



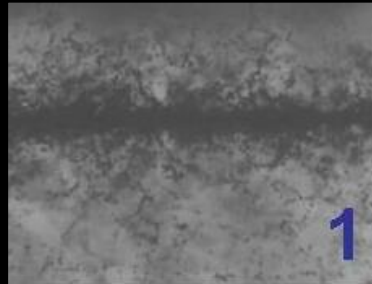
BECQUEREL
PROJECT

Проект
БЕККЕРЕЛЬ

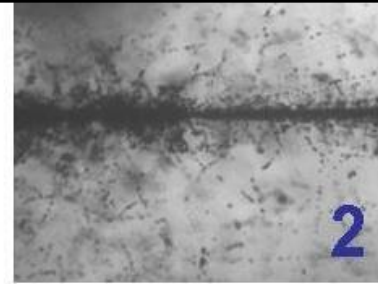
Beryllium (Boron)
Clustering
Quest in
Relativistic Multifragmentation

<http://becquerel.jinr.ru>

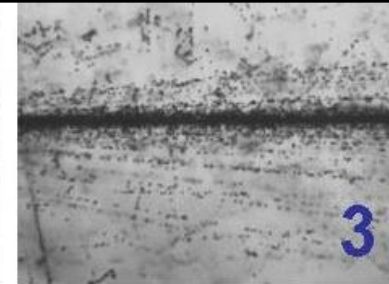
Irina Zarubina “Imaging of few-body nuclear systems in nuclear track emulsion ”



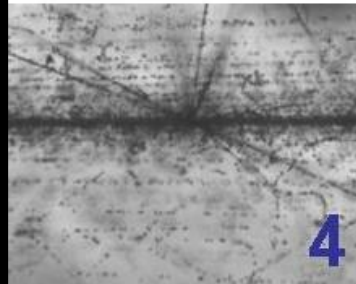
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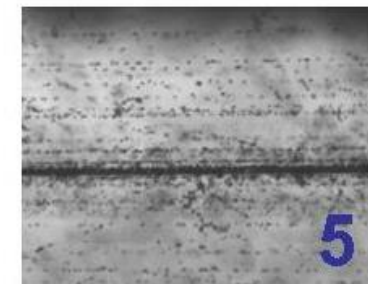
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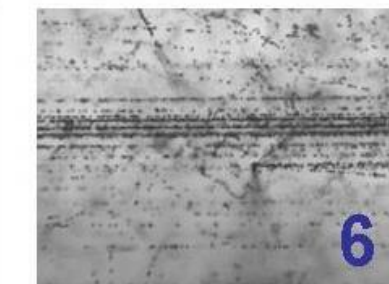
3



4



5



6

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

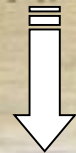
Crystal of silver-bromide - $0.2 \mu\text{m}$

Atom - $10^{-4} \mu\text{m}$

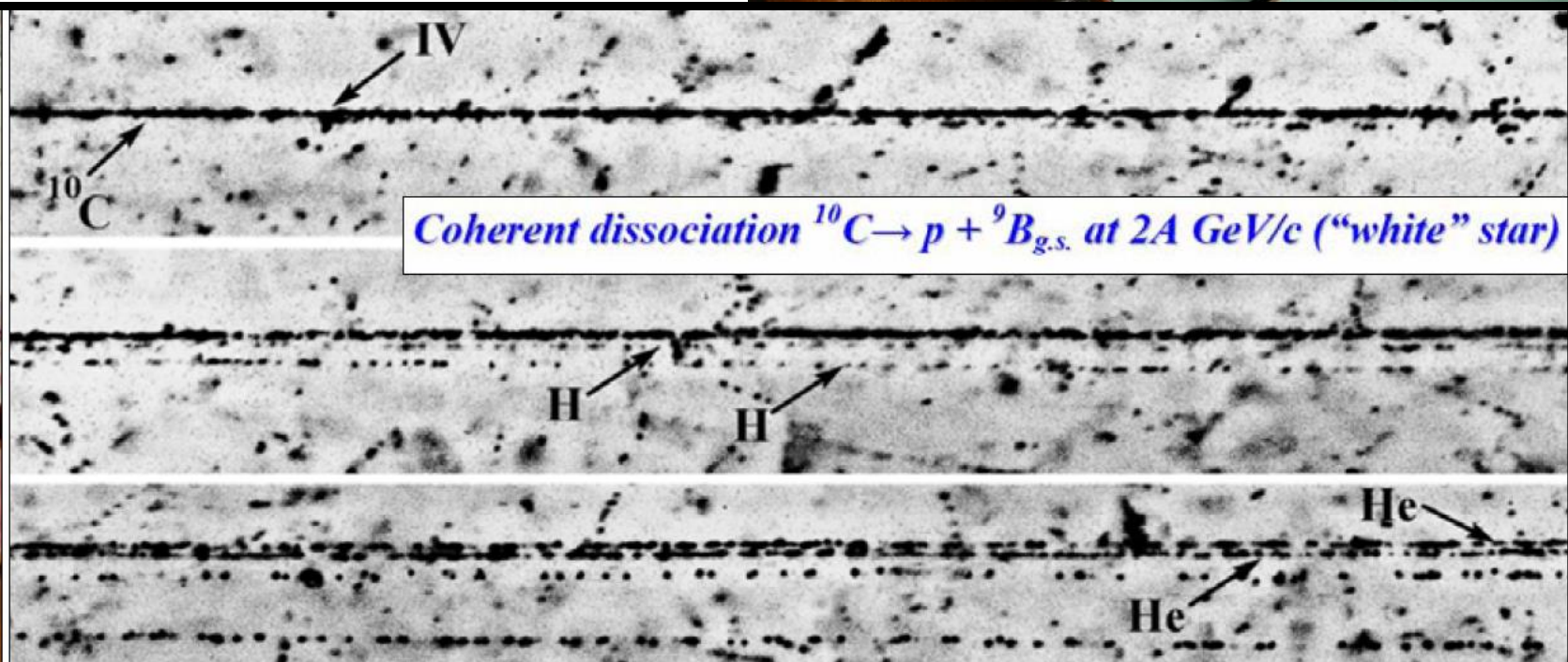
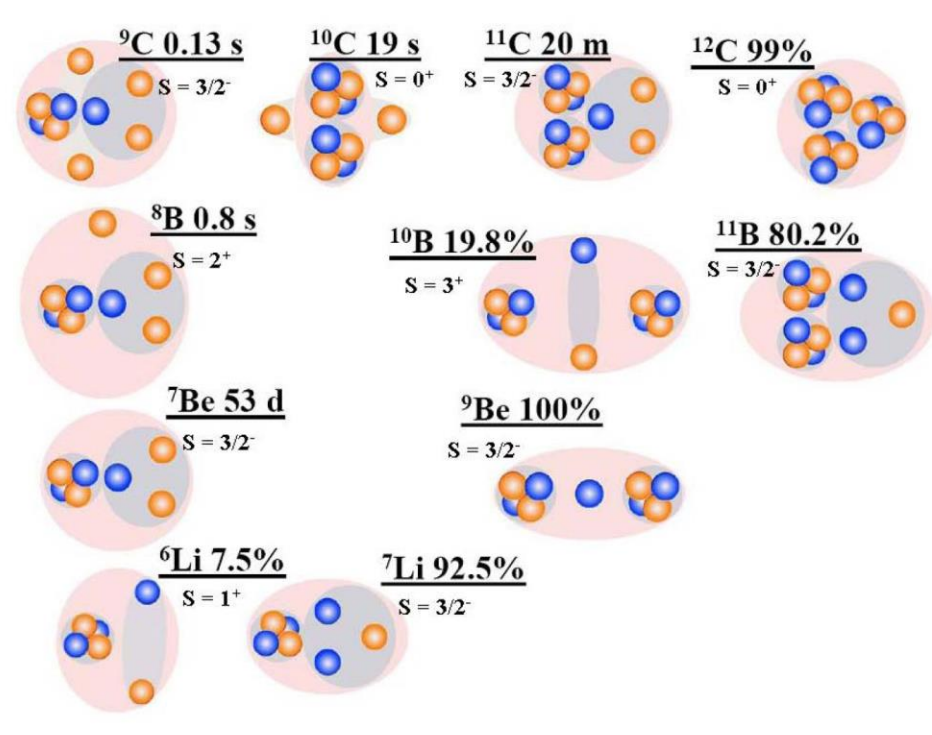
Proton - $10^{-9} \mu\text{m}$



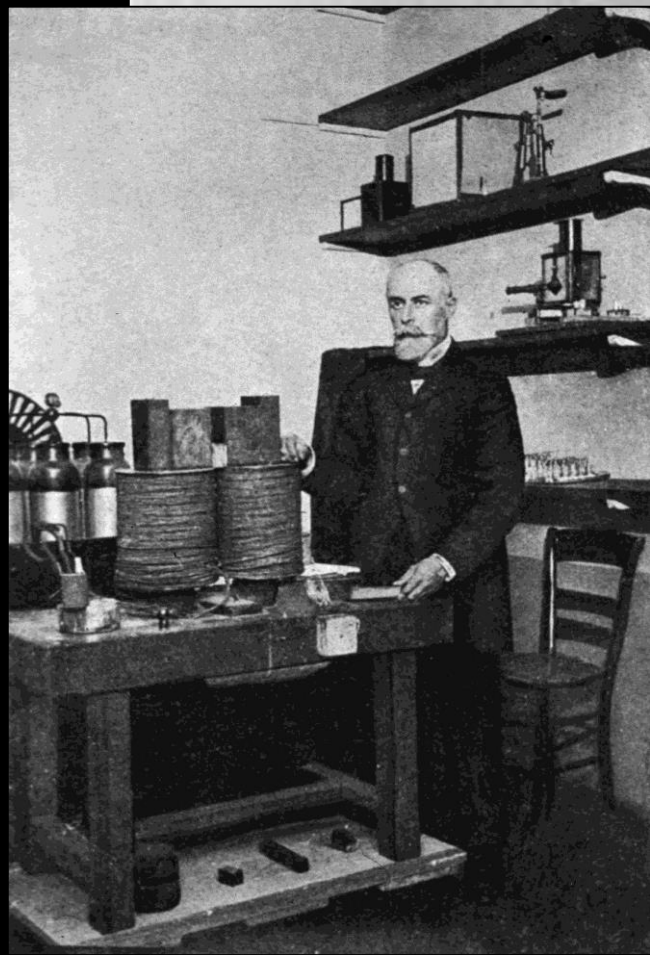
$60 \mu\text{m}$



**Human hair superposed on a nuclear star
produced by relativistic sulfur nucleus**



60 - 1890. . . Sulfate d'Ammoniac et de Potasse
Papier noir. Cuvier de laiton lustré.
Expérience au total le 27. et à la lampe diffuse le 26. -
Proust le 15 mars.





THE STUDY OF
ELEMENTARY PARTICLES
BY THE PHOTOGRAPHIC METHOD

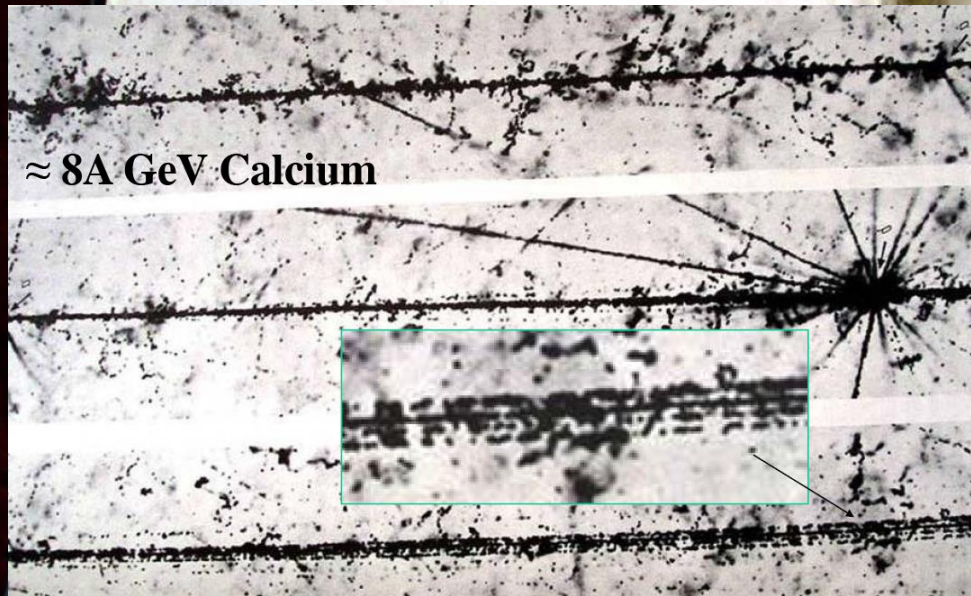
An account of
The Principal Techniques and Discoveries
illustrated by
An Atlas of Photomicrographs

BY
C. F. POWELL
P. H. FOWLER and D. H. PERKINS
H. R. WILLS PHYSICAL LABORATORY
UNIVERSITY OF BRISTOL

ОБЪЕДИНЕННЫЙ ИНСТИТУТ
ЯДЕРНОЙ ФИЗИКИ
БИБЛИОТЕКА

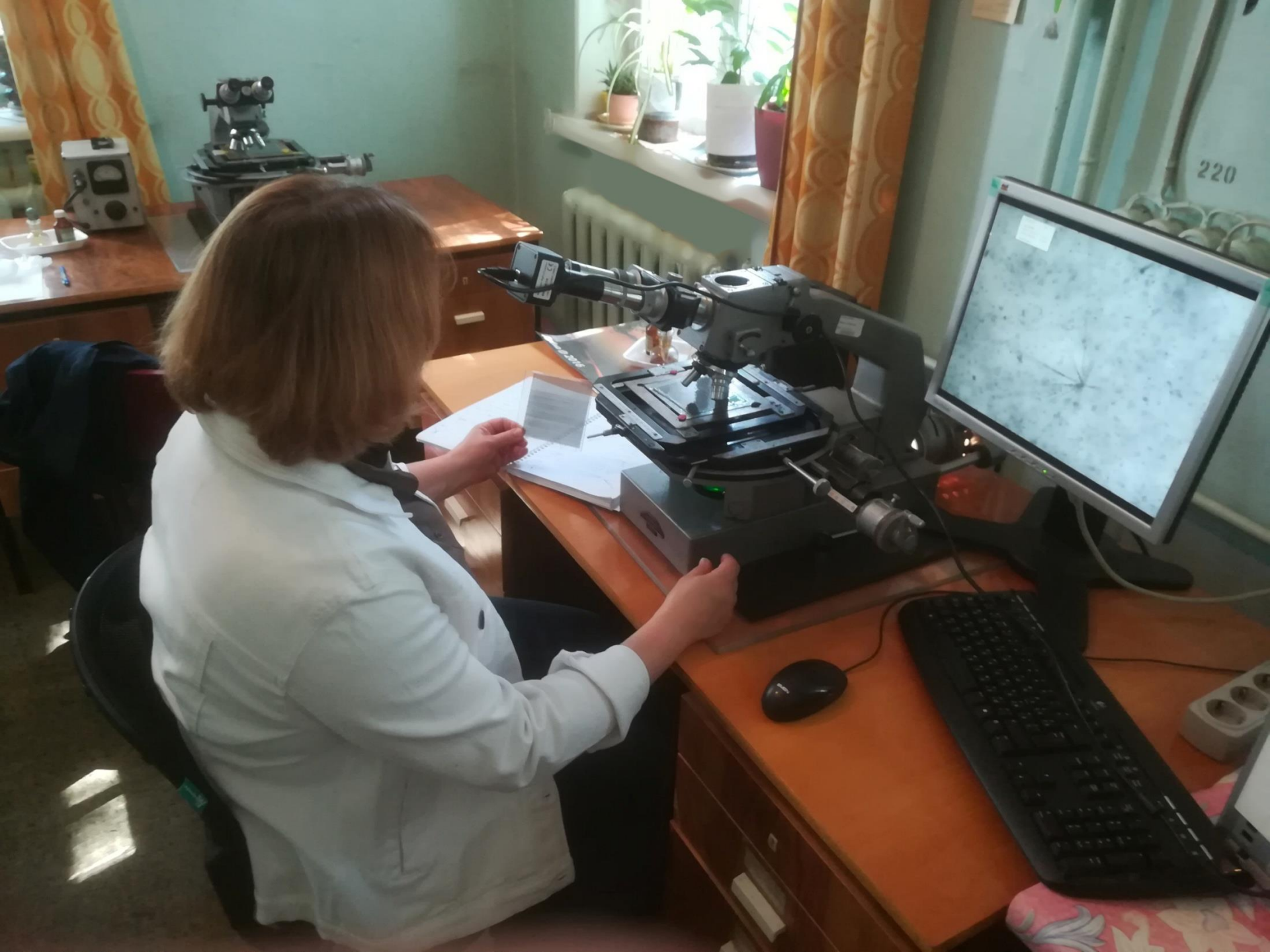


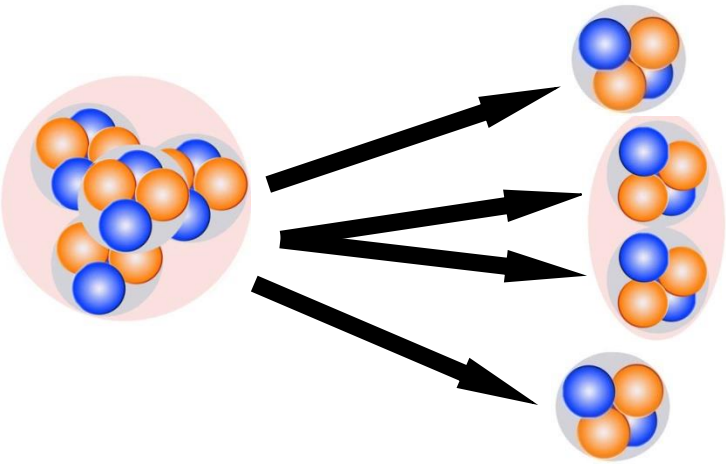
PERGAMON PRESS
LONDON · NEW YORK · PARIS · LOS ANGELES
1959



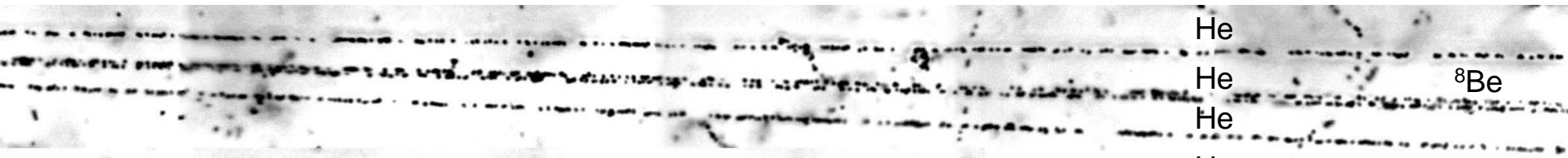
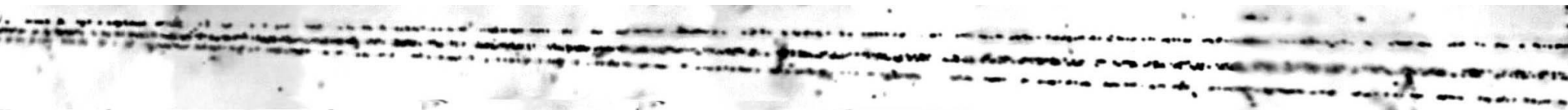
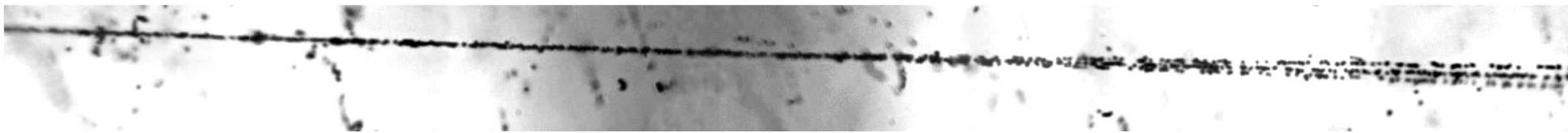
$\approx 8A$ GeV Calcium

Events of multiple fragmentation of relativistic nuclei were observed as early as the 40s in the NTE exposed to cosmic rays in the stratosphere. Their photographs presented in the classic book by C. H. Powell, P. H. Fowler and D. H. Perkins, among other fundamental observations can serve as a model of clarity in our time. Our research is implemented in keeping with this tradition.





4.5 A GeV/c ¹⁶O
JINR SPhT 80-ies



He

He

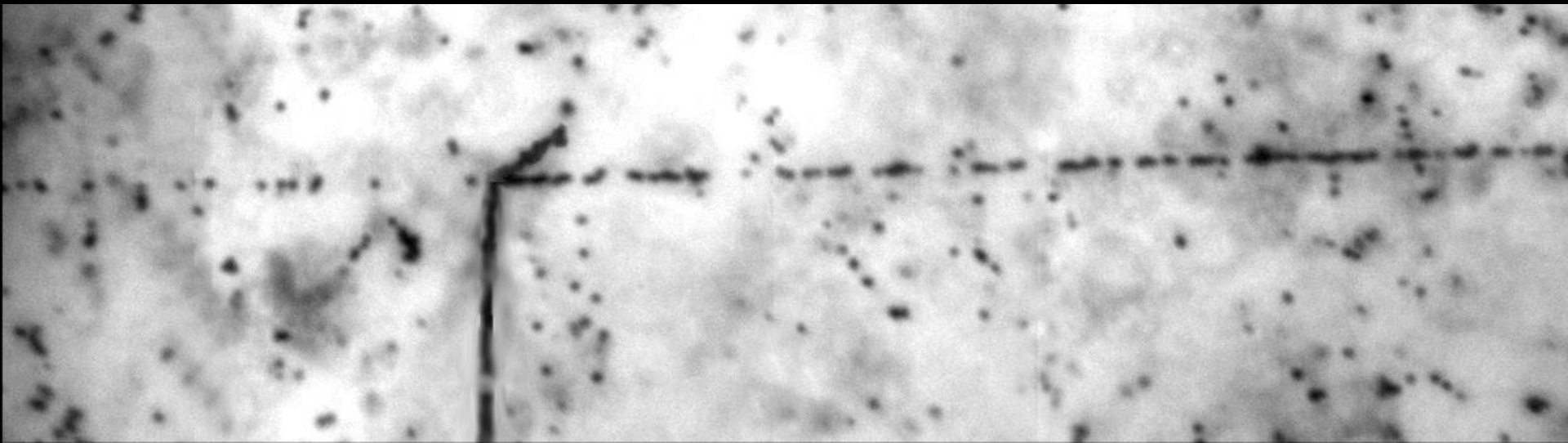
He

He

⁸Be

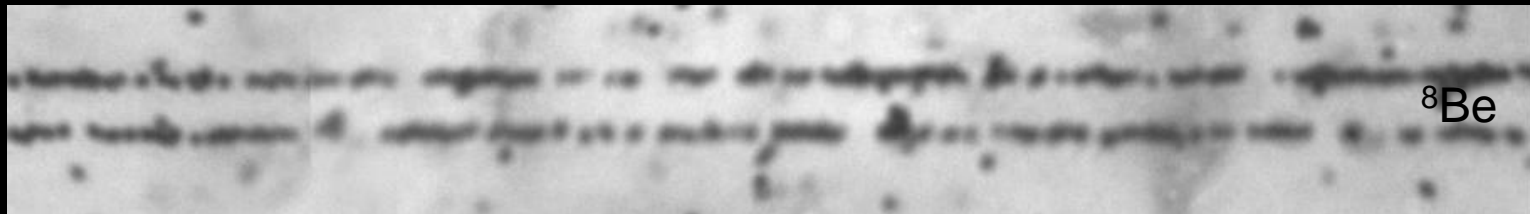
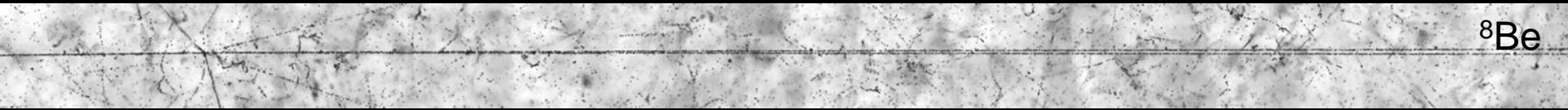
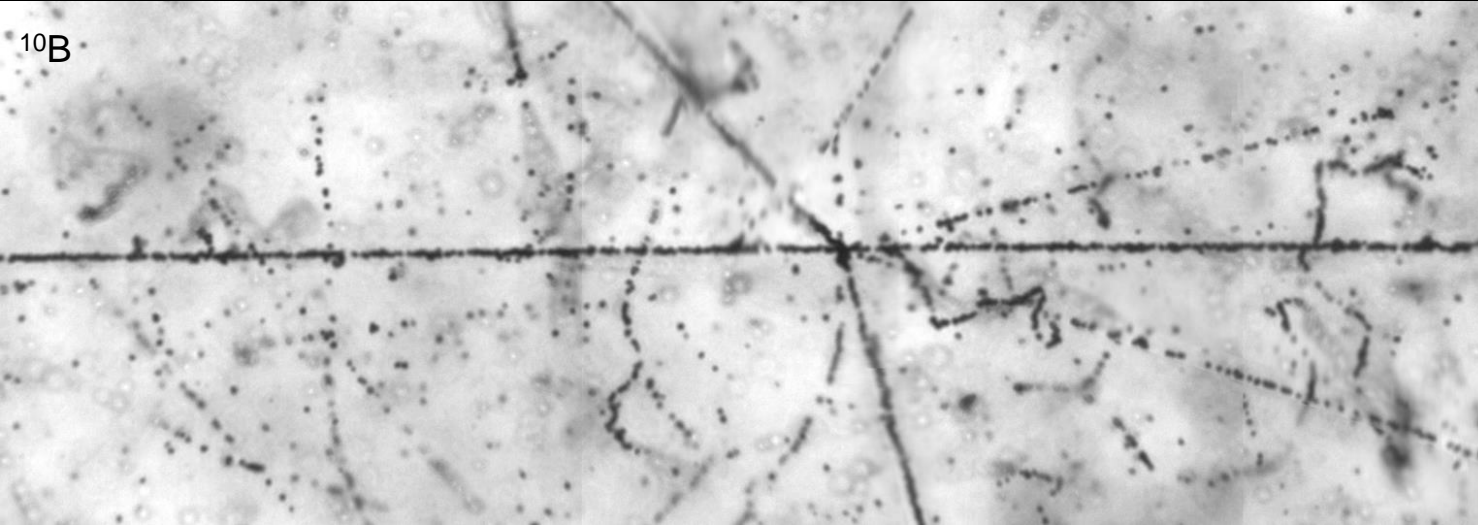
2.7 A GeV/c ^3H

JINR SPhT late 90-ies

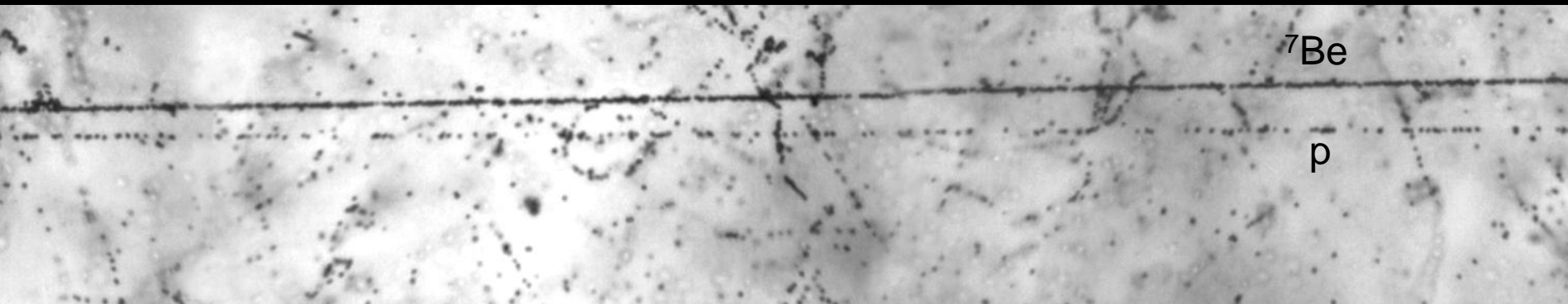
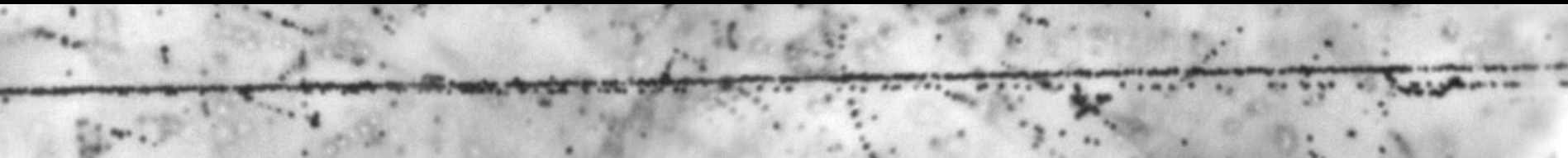


$2.0 A \text{ GeV}/c \text{ } ^9\text{Be} \rightarrow \text{}^8\text{Be}(\rightarrow 2\text{He}) + 2b + 2g$

JINR Nuclotron mid 2000-ies



2.0 A GeV/c ^8B \rightarrow ^7Be + p “white” star JINR Nuclotron mid 2000-ies





Boron-enriched samples of NTE (boric acid and borax), were irradiated for 30 minutes at the thermal neutron channel of the IBR-2 reactor JINR .

IBR-2 15min Boron 500mkm_x60

A black and white micrograph showing a dense field of dark, irregular tracks and spots on a light, grainy background. The tracks vary in length and thickness, some appearing as short, thick segments while others are longer and thinner. The overall appearance is that of a complex, interconnected network of etched features.

The presence of boron in NTE allows one to observe tracks of ${}^7\text{Li}$ and ${}^4\text{He}$

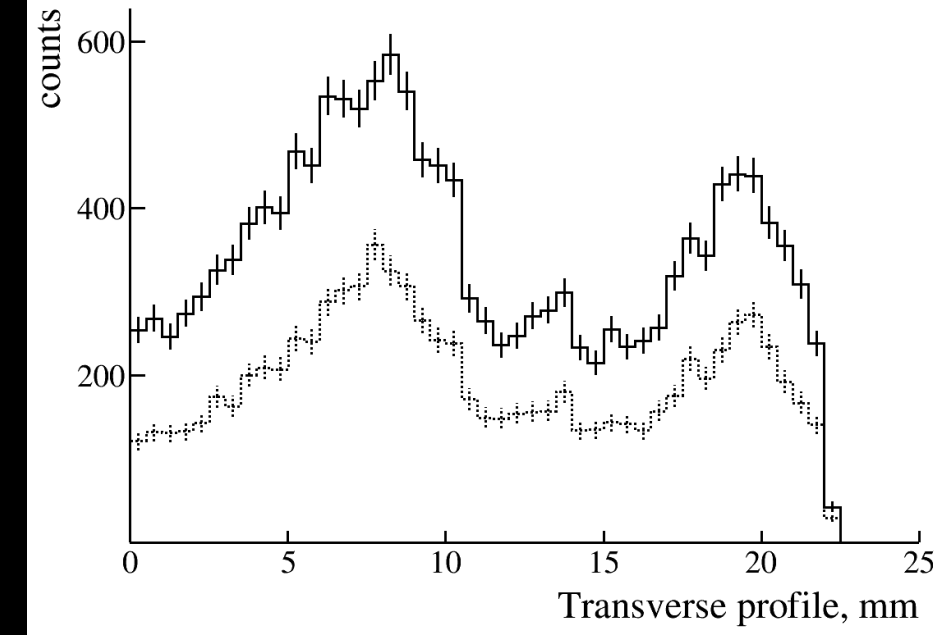
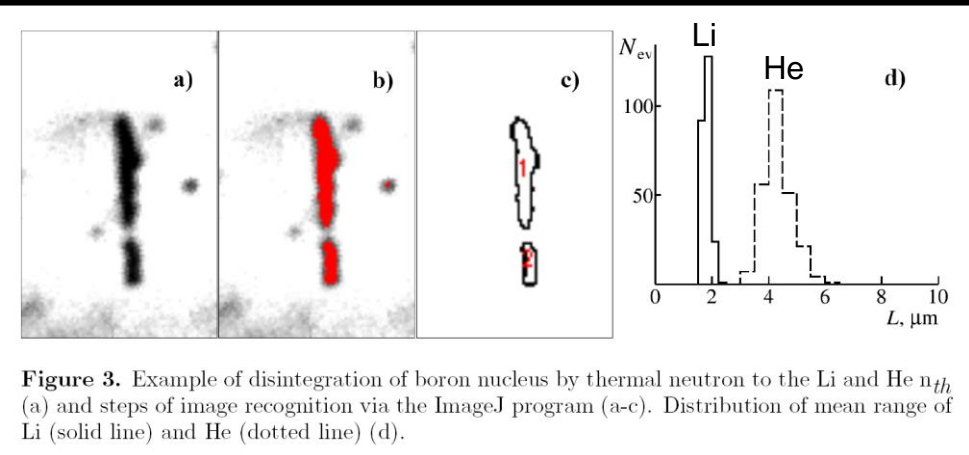
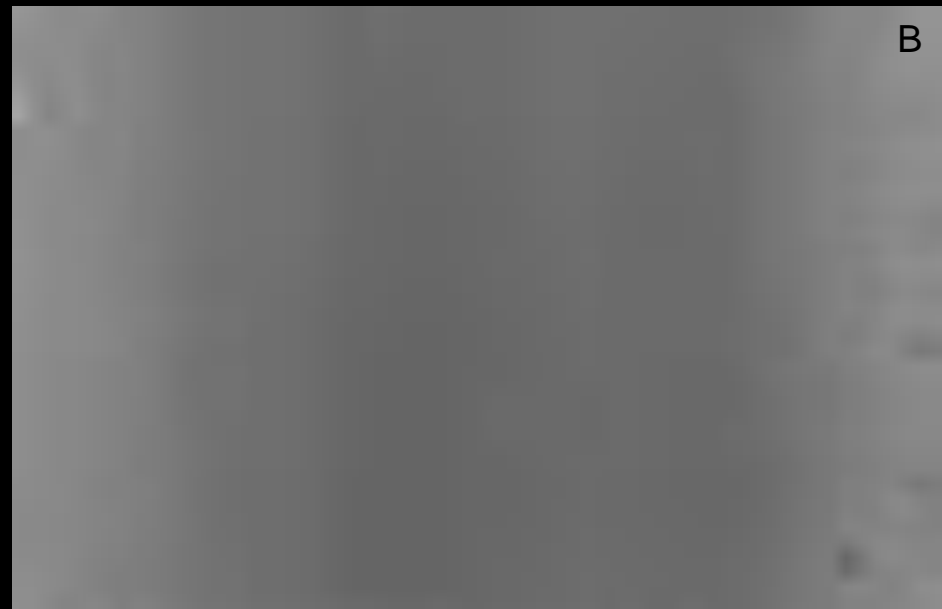
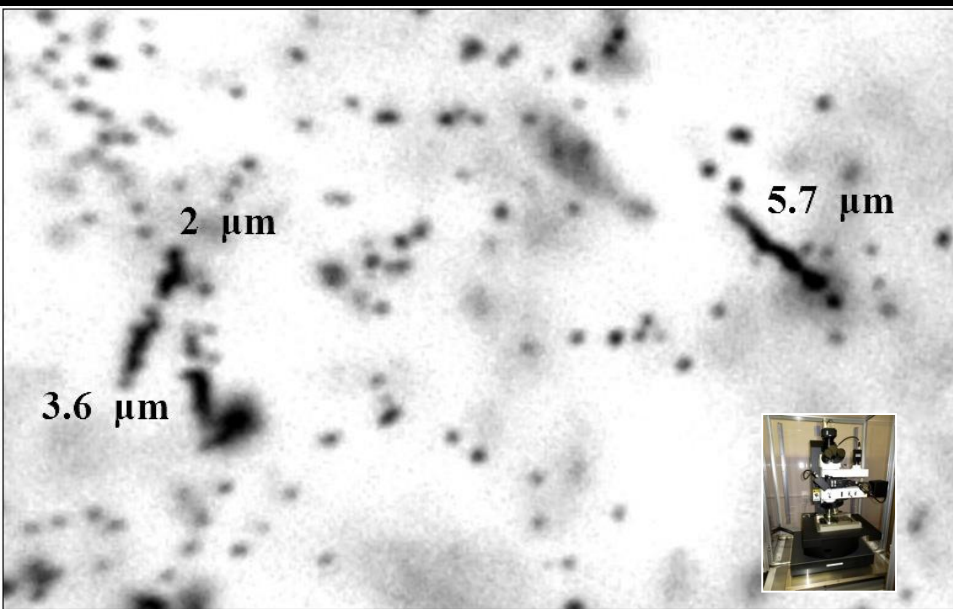
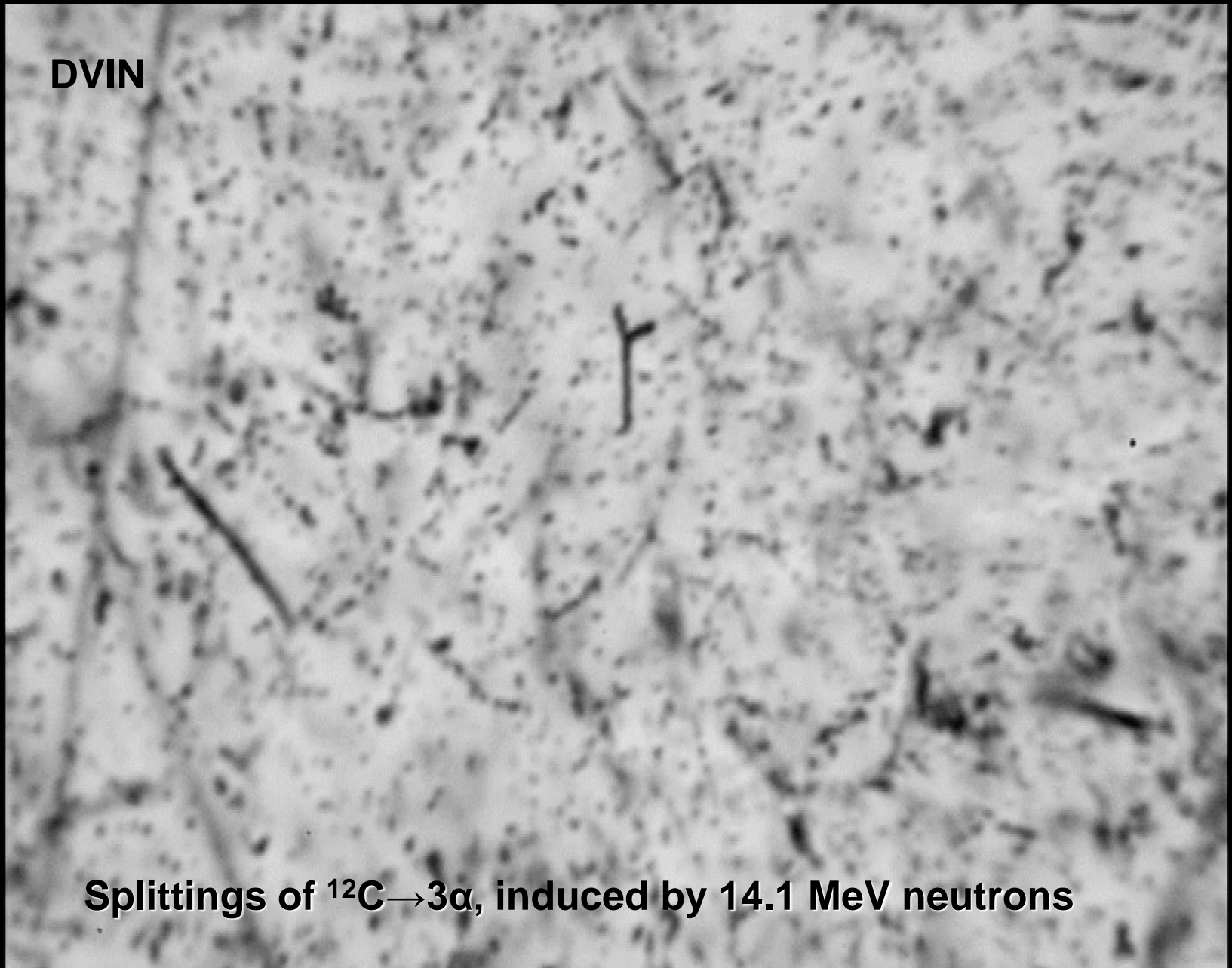


Figure 3. Example of disintegration of boron nucleus by thermal neutron to the Li and He n_{th} (a) and steps of image recognition via the ImageJ program (a-c). Distribution of mean range of Li (solid line) and He (dotted line) (d).

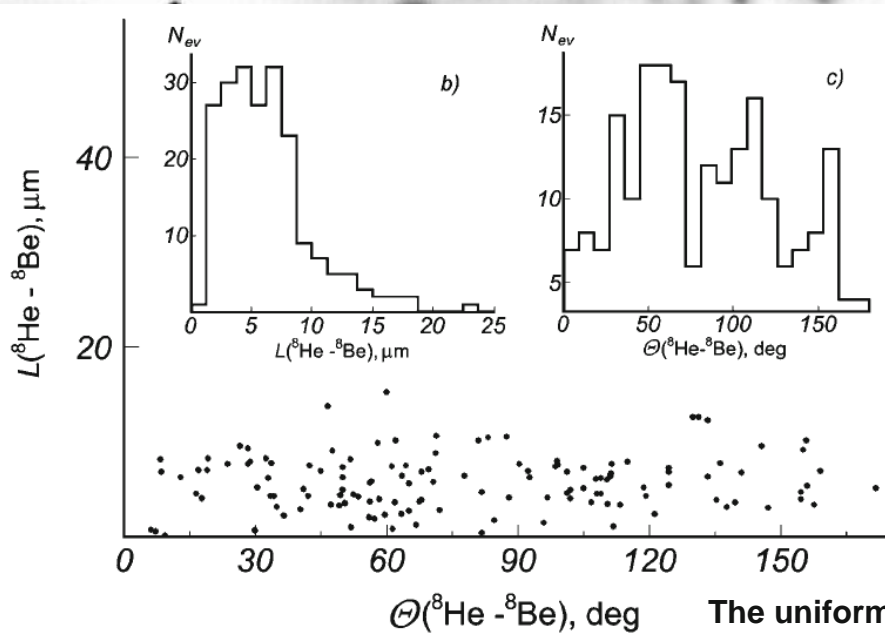
DVIN

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



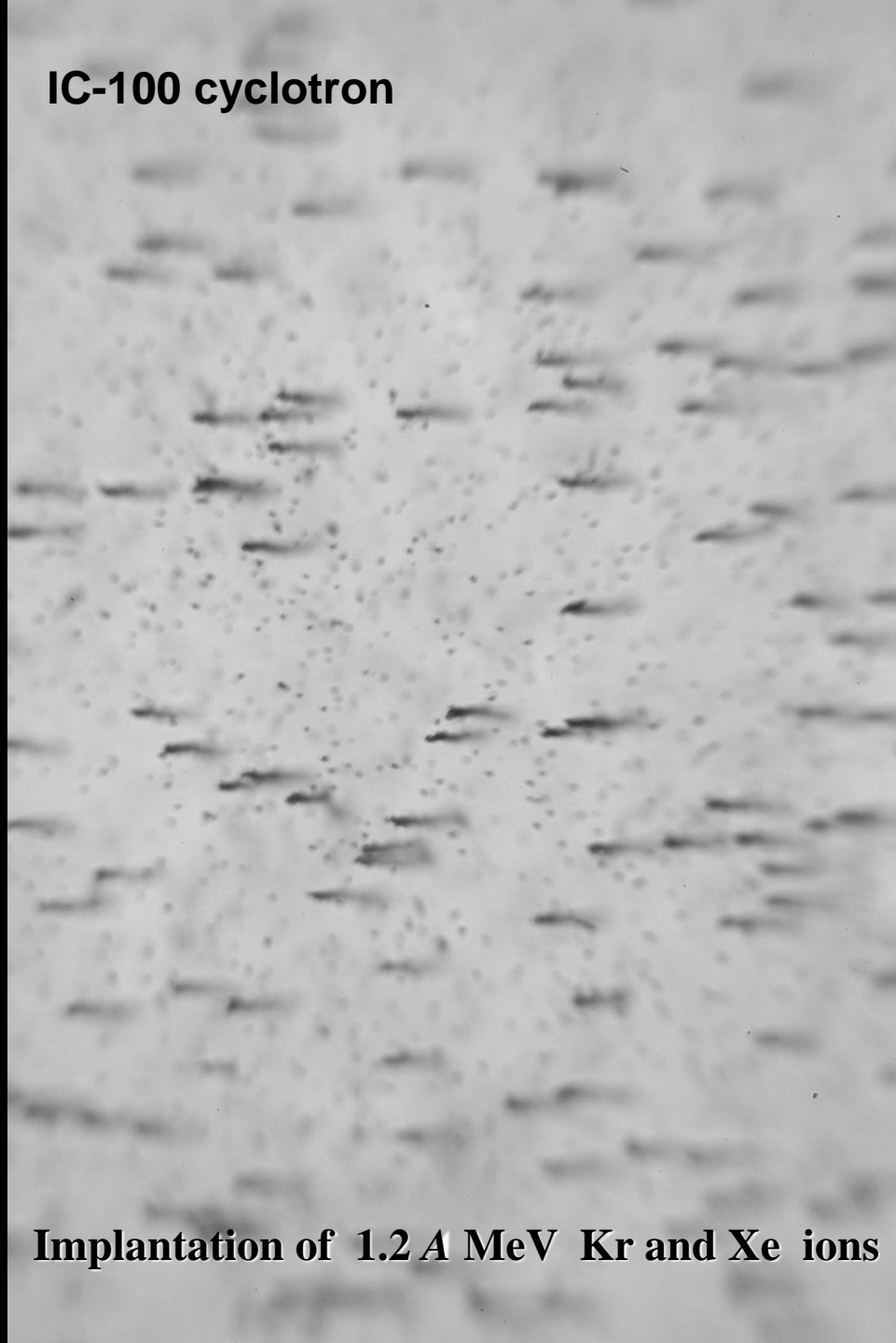
ACCULINNA

^8He



The uniform angular distribution confirms a thermal drift of the atoms ^8He

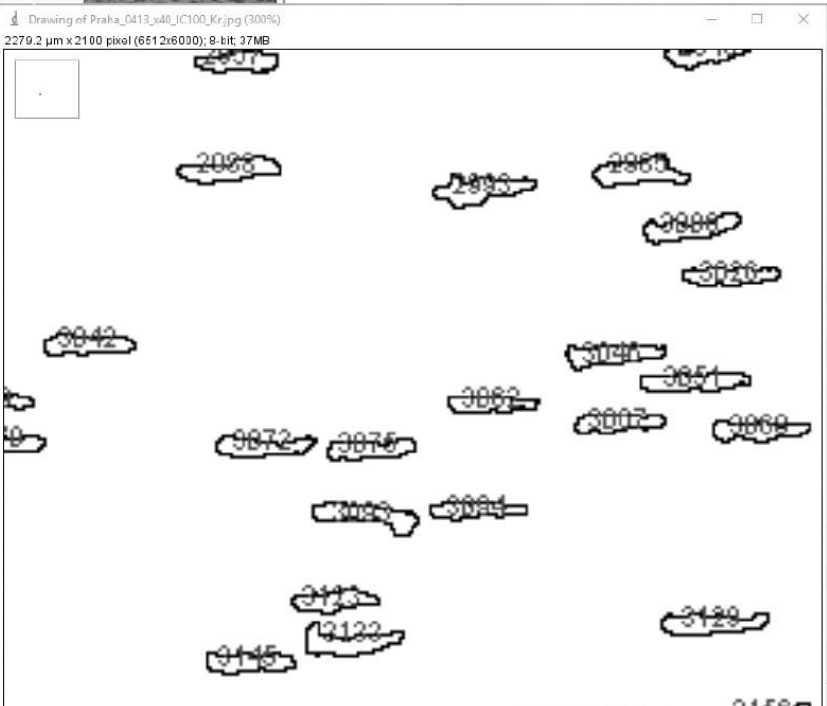
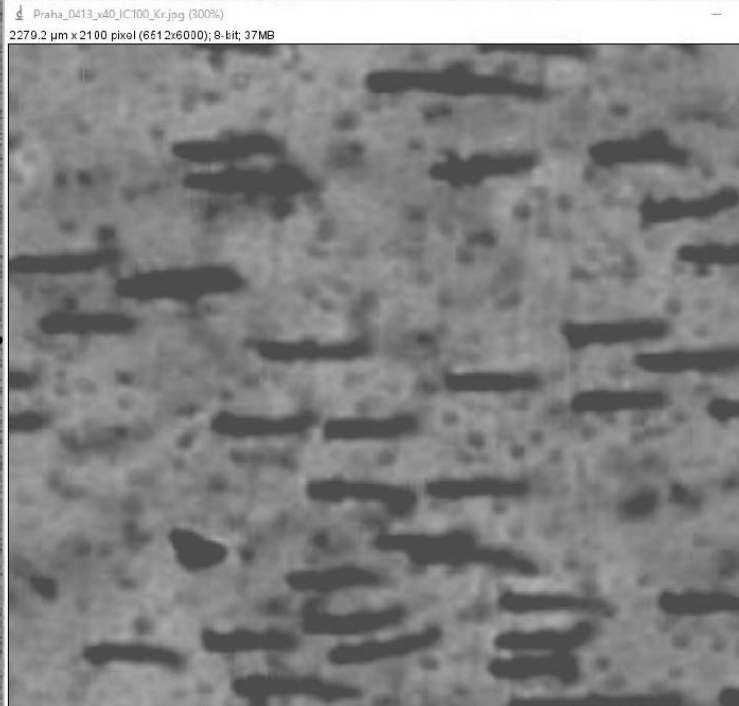
IC-100 cyclotron



Implantation of 1.2 A MeV Kr and Xe ions

Praha_0413_x40_IC100_Kr.jpg (12.5%)

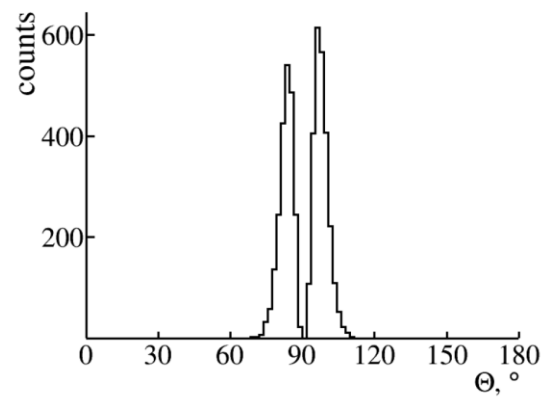
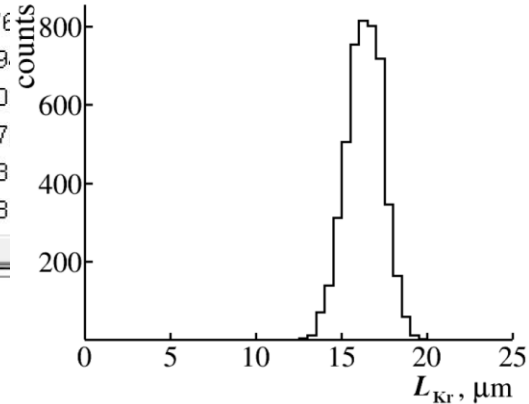
2279.2 μm x 2100 pixel (6512x6000); 8-bit; 37MB



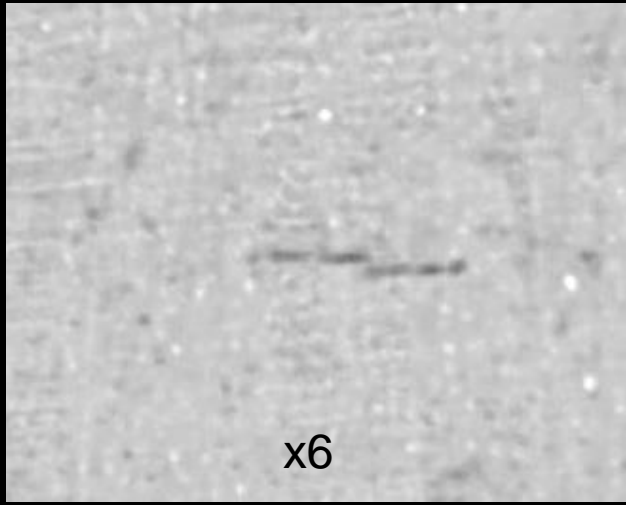
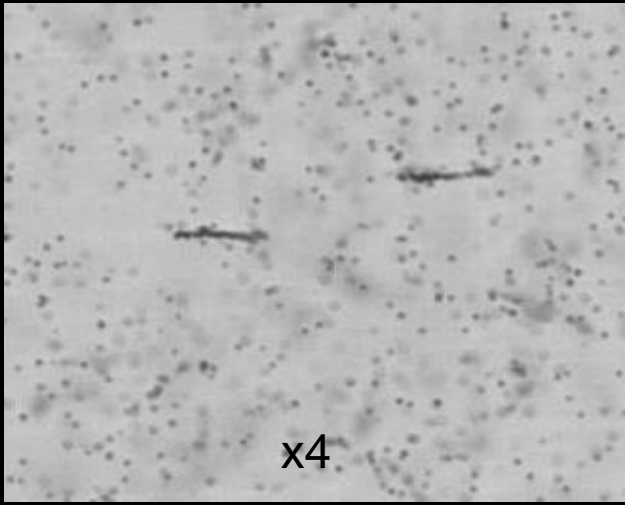
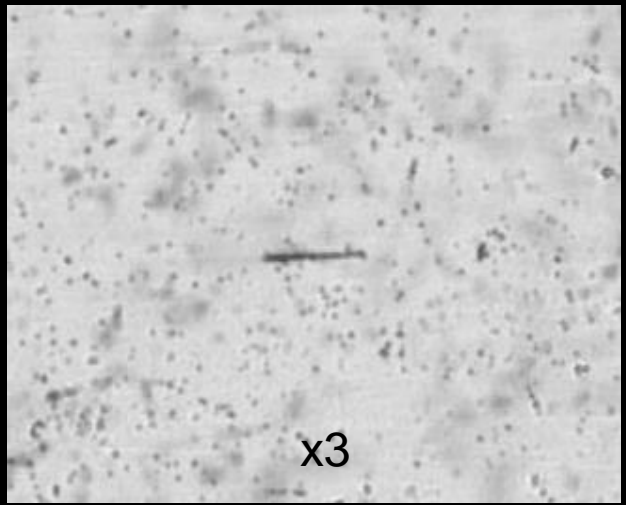
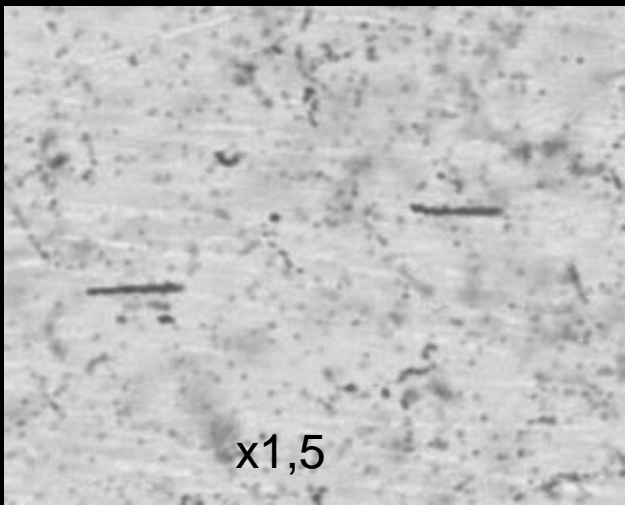
Results

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	17.6								
3185	16.292	623.072	1314.512	23.730	11.391	1.821	0.9								
3186	16.905	1175.295	1315.224	23.984	10.918	1.971	4.0								
3187	21.560	1502.451	1315.145	22.584	9.231	2.974	0.7								
3188	23.397	943.595	1315.473	25.420	11.721	2.542	3.3								
3189	22.417	2158.895	1315.555	25.589	10.935	2.610	2.8								

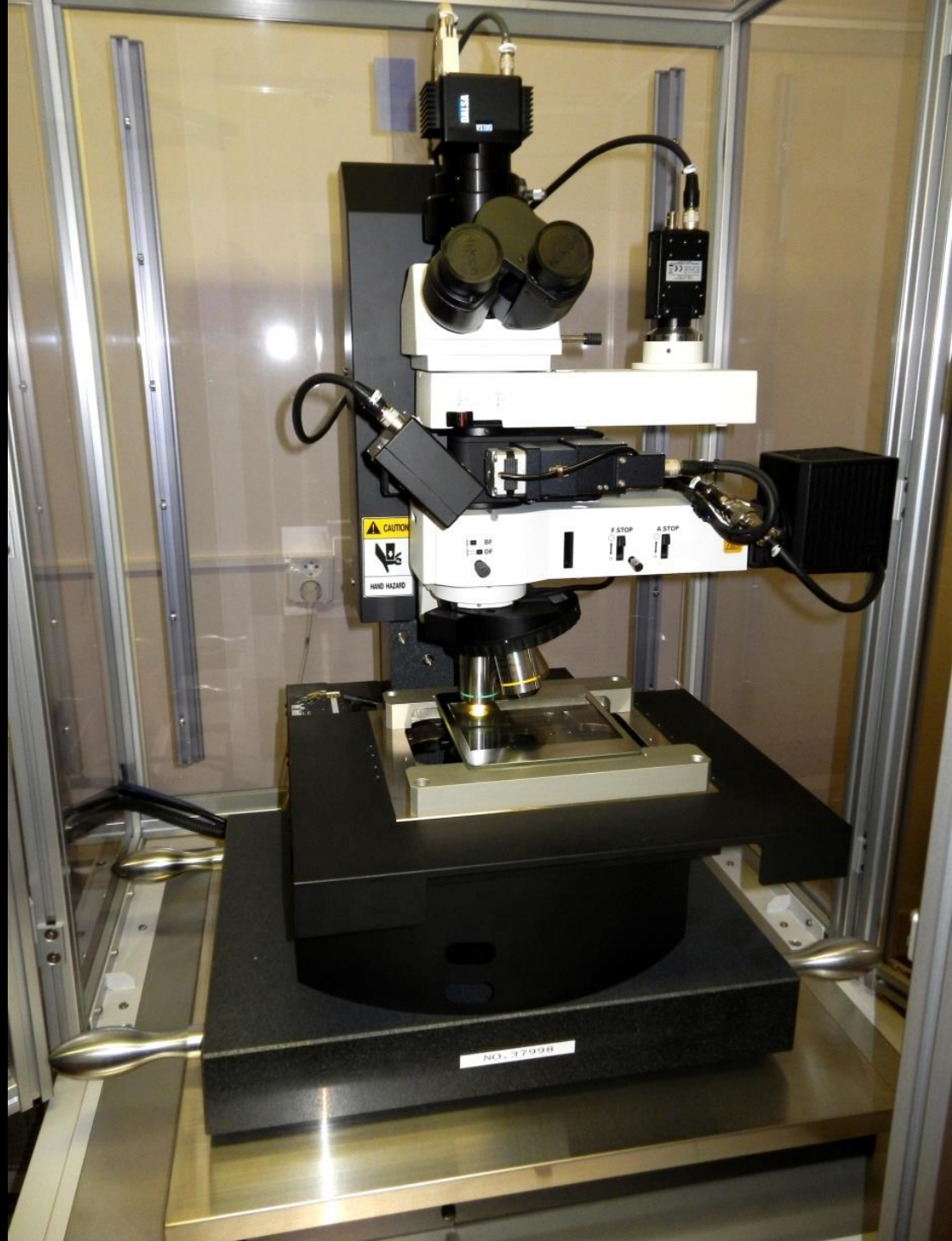
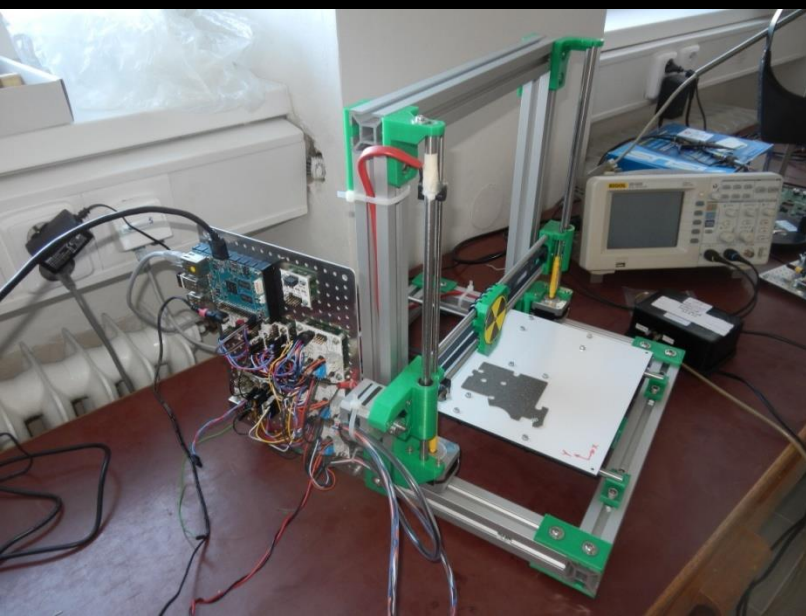


The ImageJ program

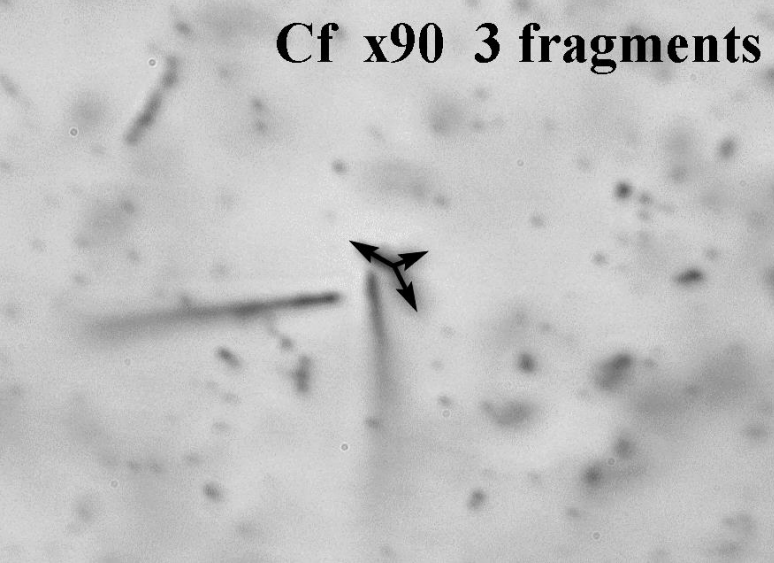


Diluted emulsion exposed to Xe ions

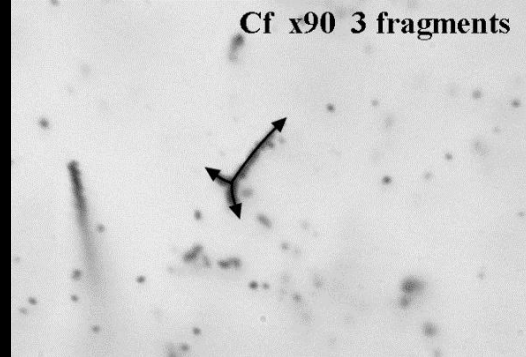
A large-scale NTE scanning is suggested to be performed on the microscope HSP-1000 of the Department of radiation dosimetry (DRD) of Nuclear Physics Institute of the Academy of Czech Republic. The use of the NTE resolution will be full if the microscope will be adapted to operate with lenses of the highest 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.



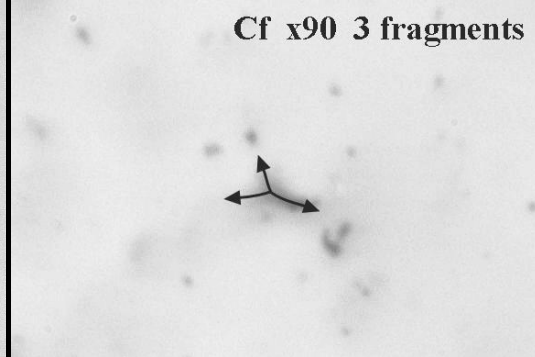
Cf x90 3 fragments



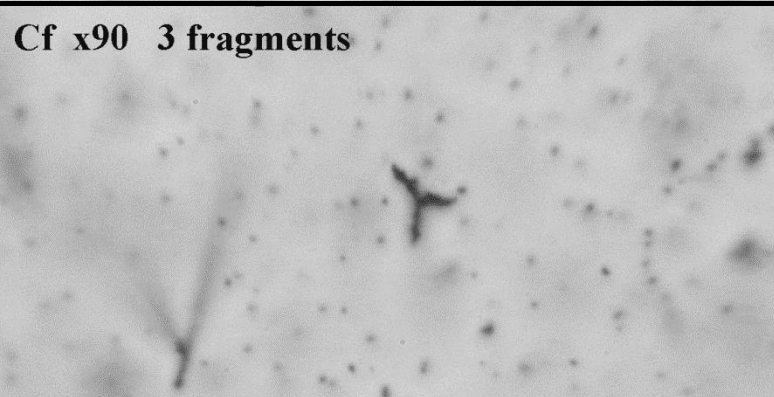
Cf x90 3 fragments



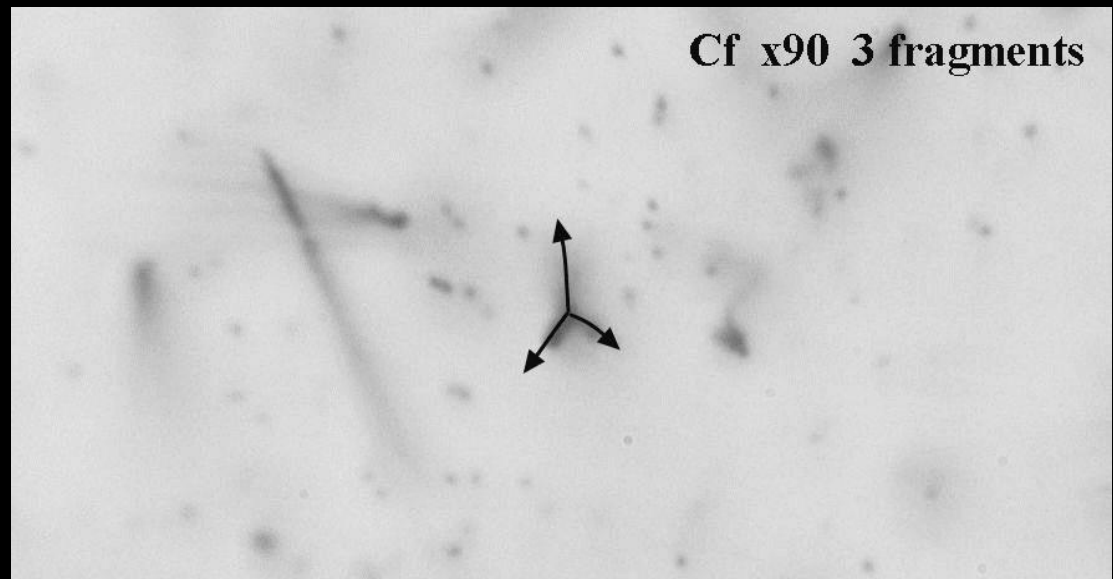
Cf x90 3 fragments



Cf x90 3 fragments



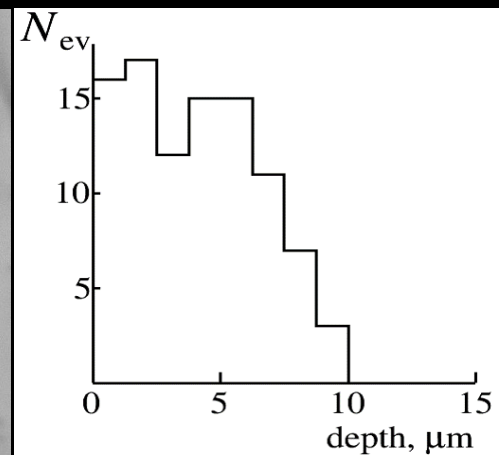
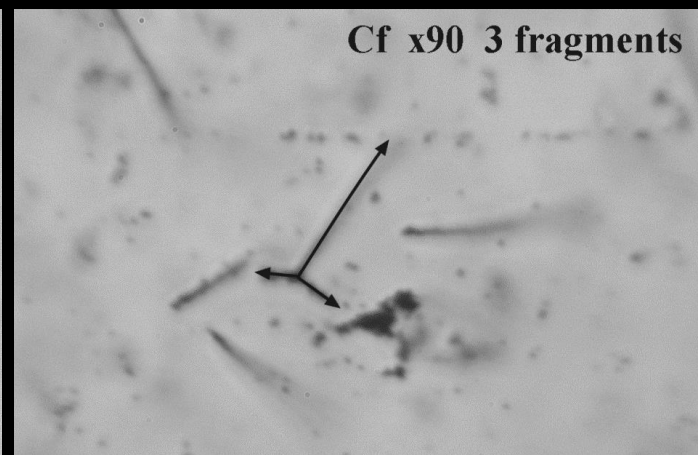
Cf x90 3 fragments



Cf x90 3 fragments



Cf x90 3 fragments





**Nuclear education with
nuclear track emulsion**



Despite of the fact that half a century has passed since its development, the nuclear track emulsion retains the status of a universal and inexpensive detector. Due to the record spatial resolution (about $0.5\mu\text{m}$), this method provides a complete observation of tracks, beginning with fragments of fission and up to relativistic particles.

The method of nuclear emulsion deserves further application in fundamental and applied research of modern accelerators and reactors and sources of radioactivity, including natural ones. Application of NTE is especially justified in those pioneering experiments in which tracks of nuclear particles cannot be reconstructed by electronic detectors in <http://becquerel.jinr.ru/>

We have created an extensive collection of macrophotos and videos about the interactions of relativistic nuclei and in low-energy physics.

Our goal is to draw attention to the ever-growing collection. Our materials can be easily accessed and used to develop intuition, to inspire new researches and pedagogical work.

Despite of the fact that half a century has passed since its development, the nuclear track emulsion retains the status of a universal and inexpensive detector. Due to the record spatial resolution (about $0.5\mu\text{m}$), this method provides a complete observation of tracks, beginning with fragments of fission and up to relativistic particles. The method of nuclear emulsion deserves further application in fundamental and applied research of modern accelerators and reactors and sources of radioactivity, including natural ones. Application of NTE is especially justified in those pioneering experiments in which tracks of nuclear particles cannot be reconstructed by electronic detectors.

The NTE technique is still based on intelligence, vision and performance of researchers using traditional microscopes.

Despite wide interest, its labor consumption causes limited sampling 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 NTE analysis allows one to bridge this gap.

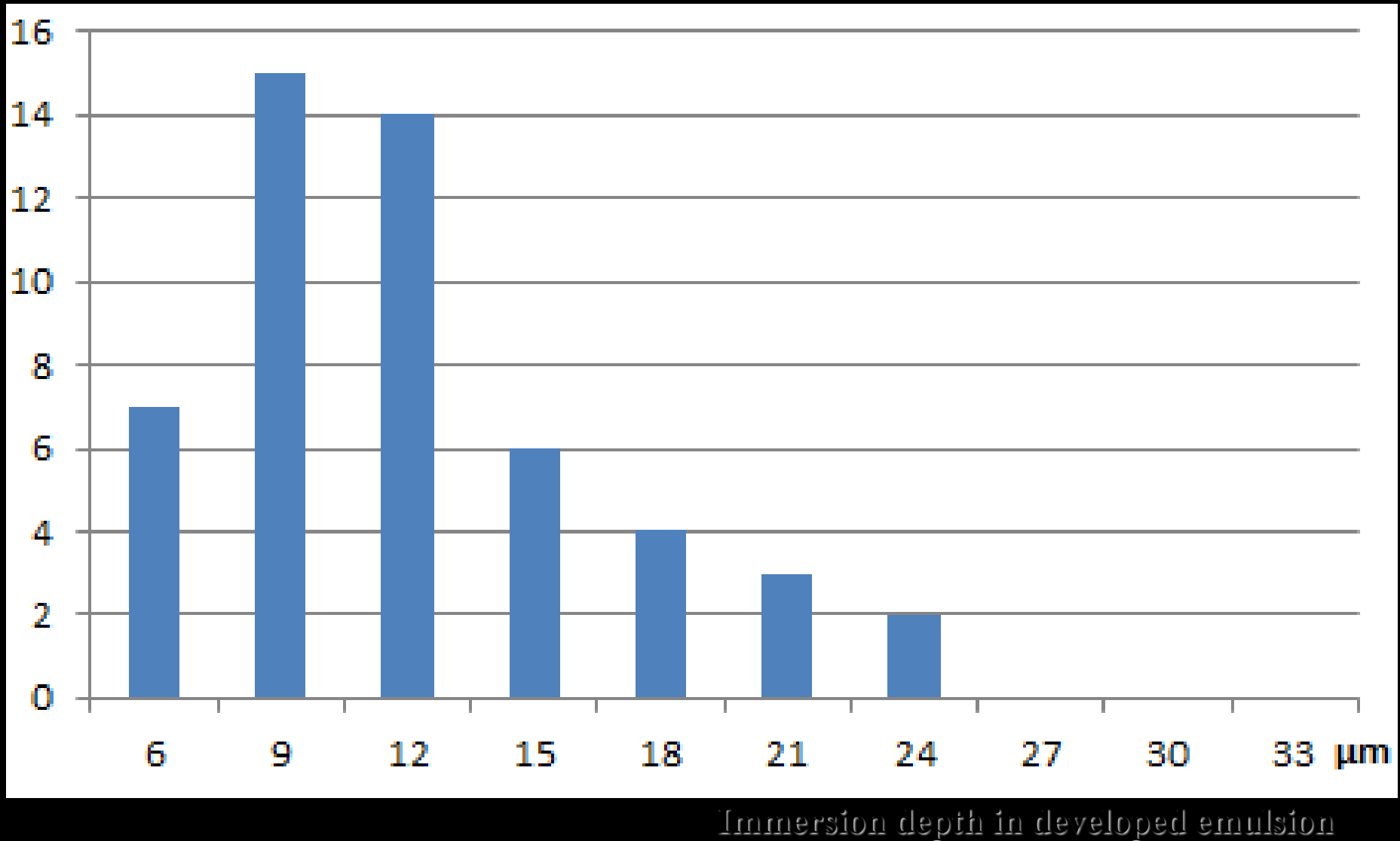
These are complicated and expensive devices of collective or even remote use, which allow us to describe the record statistics of short nuclear tracks.

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

JINR U April 2018 pl. 2_1 x20 step 1 μm



Number of planar α -tracks per 1 μm in 50 μ emulsion on glass soaked in solution of uranyl nitrate



CERN Muons May 2017 vi3_4
x20

