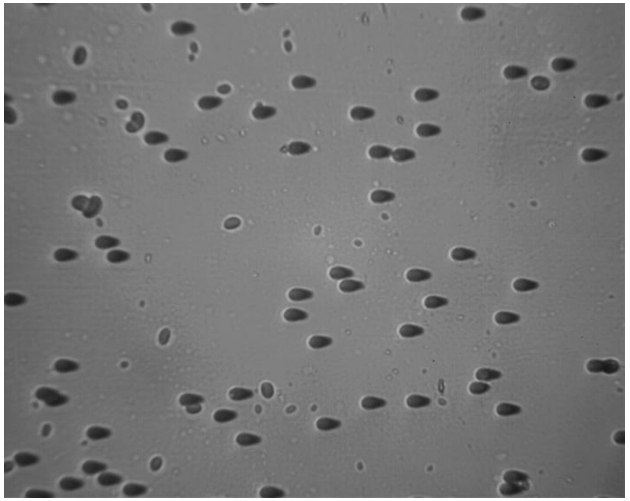
Development of method for determining the heavy ions characteristics using solid-state detectors (glass, minerals)

Starkova E.N., Polukhina N.G., Starkov N.I.,
Konovalova N.S., Okateva N.M., Chernyavskiy M.M.,
Shchedrina T.V.

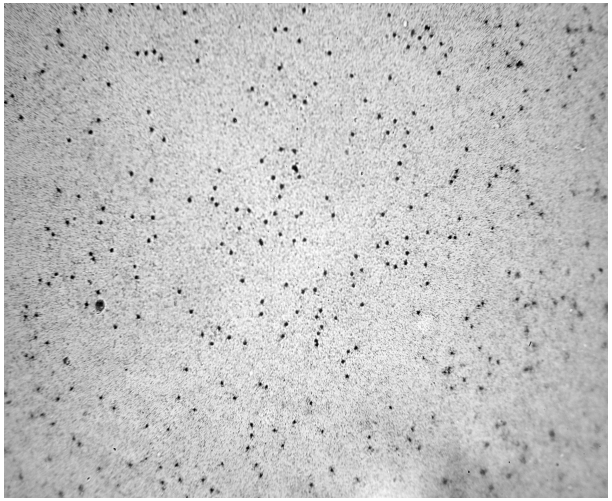
Lebedev Physical Institute 2025

- In the Laboratory elementary particles (LPI) during many years solid-states detectors are used (glasses, minerals, plastics)



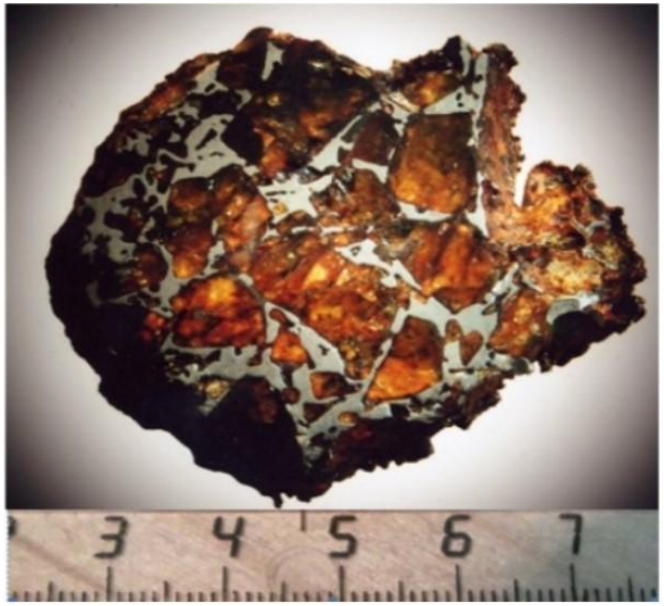
glass

olivine



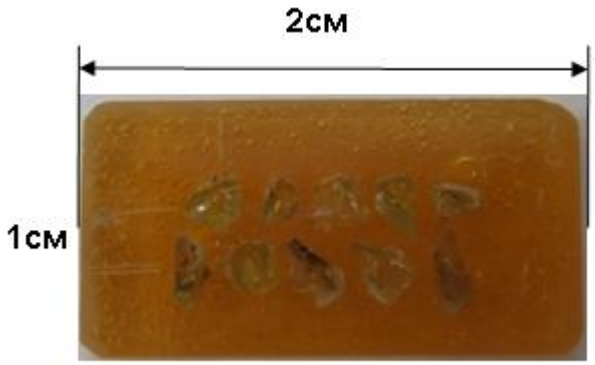
plastic

1. Determination of nuclear charge in olivine from meteorites



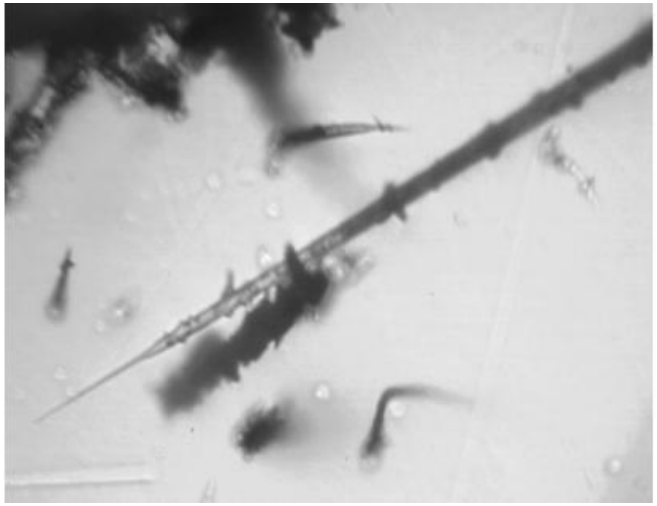
In meteorites of the palasite type, there are inclusions of transparent minerals – olivine, inside the iron-nickel matrix

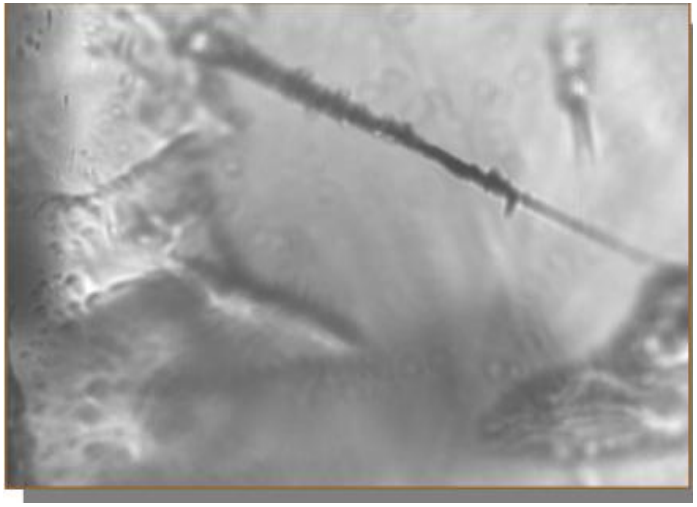
Meteorites many millions of years are exposed by cosmic rays



1. The olivine crystals are extracted.
2. Then they are placed into the epoxy tablet and etched.
3. The results of measuring are track length and etching rate.

The etching of the olivine crystals





The etching rate is higher at the points where the particle passes than that of the base material.

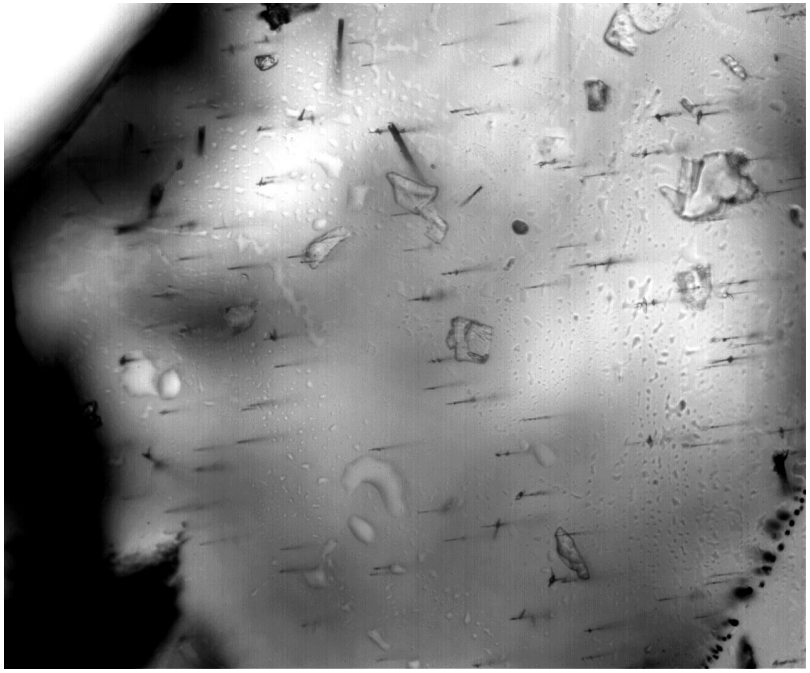
The PAVICOM facility

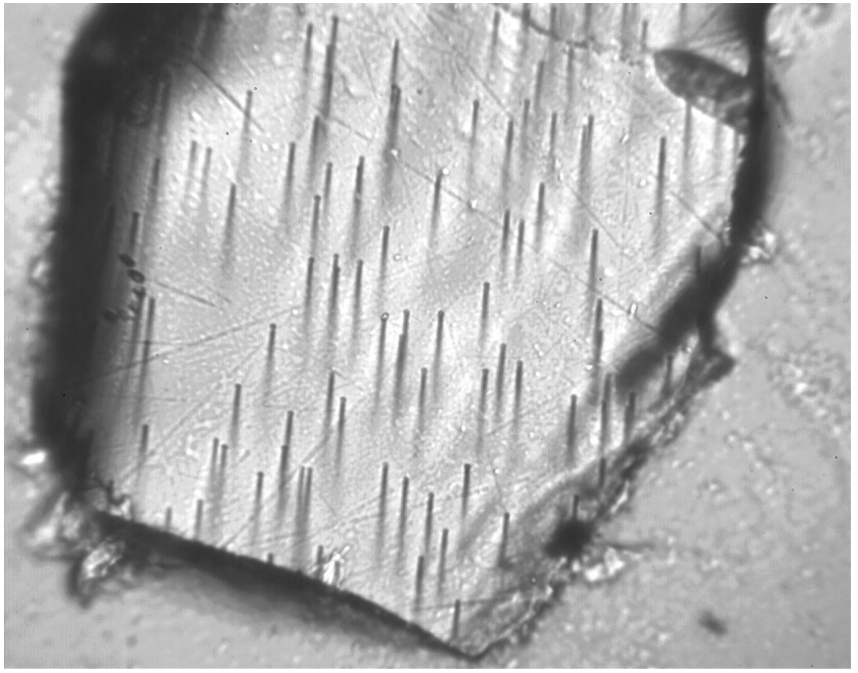
The processing of the olivine crystals is executed with the facility PAVICOM-2.

- The goal in this investigation was to get the charge distribution of galactic nuclei.
- So it was necessary to have the connection between the track length, the etching rate and nucleus charge Z(L,V)

=> Calibration experiments

Calibration irradiations of the olivine

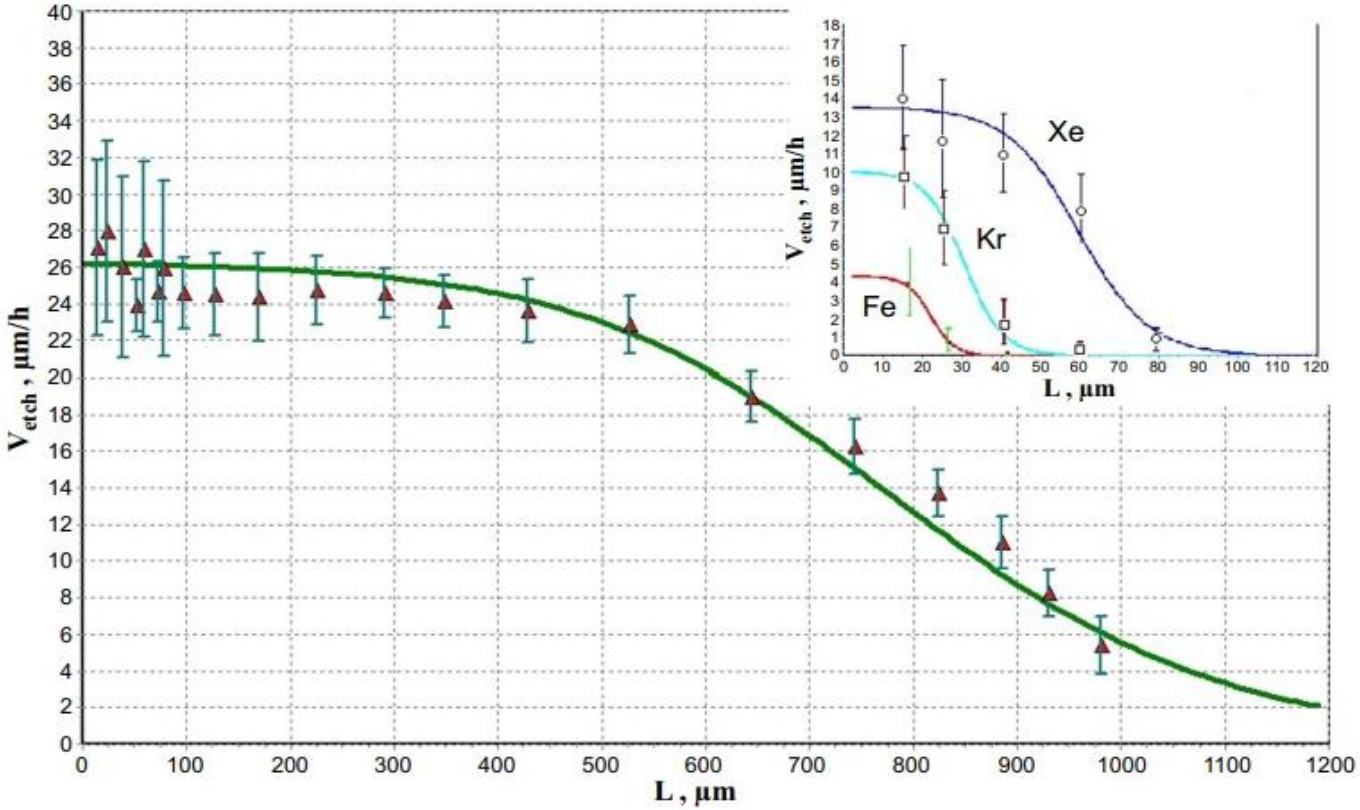




- U, E=150 MeV/A

Bi, E=11 MeV/A

The examples of the calibration experiments

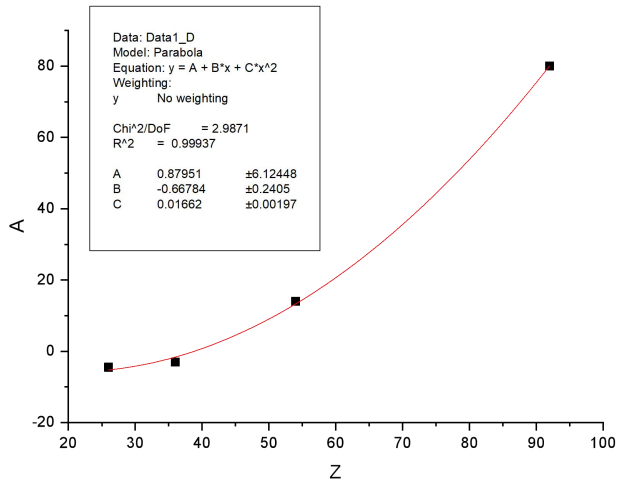


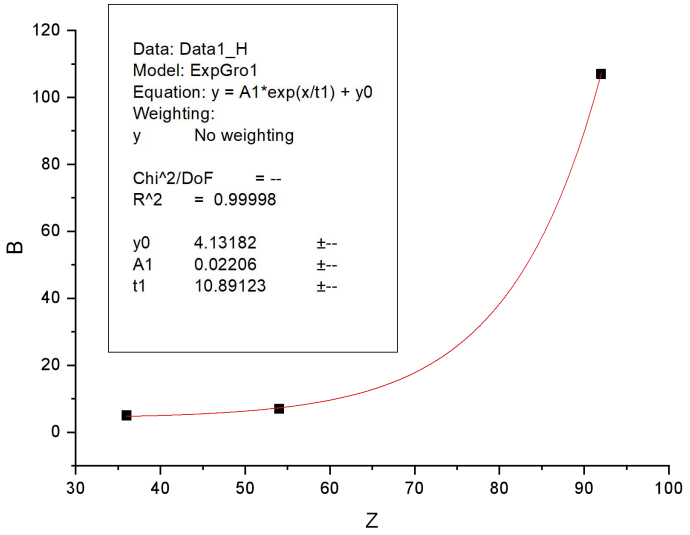
The approximation of the connection V(L,Z)

$$V(Z,L) = \frac{A(Z)\ \ (1 + E(Z)\ \ L^2)}{1 + B(Z)\ \ \exp[(L - C(Z))/D(Z)]}$$

- To extend this Z (L, V) dependence to intermediate charge values, the experimental points were approximated by the five-parameter formula

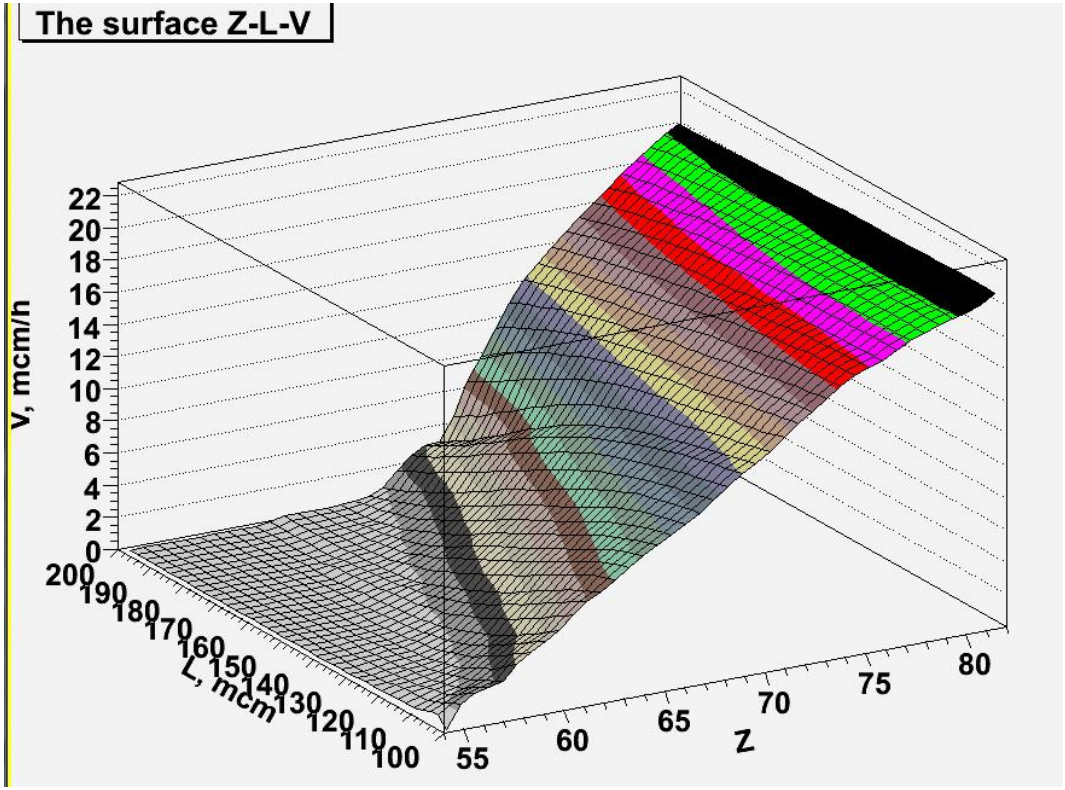
The parameter approximation by smooth functions





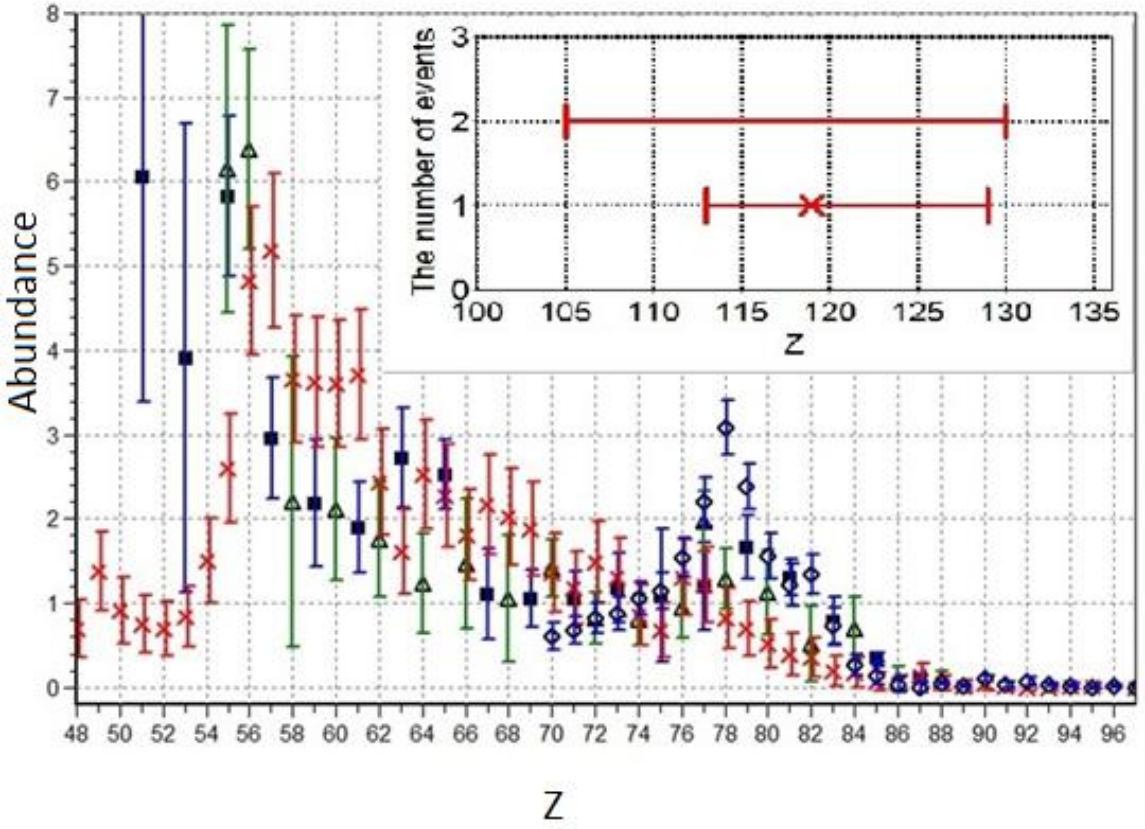
The representation of the function V(L,Z) in an analytical form makes it possible to smoothly perform not only interpolation, but also extrapolation towards nuclei heavier than uranium. Such an extrapolation cannot be very far away. In our research, it was used for nuclei with a charge up to Z = 96

The connection V(L,Z)



This function gives us possibility to determine Z using L and V which are experimental values

The charge spectrum of galactic nuclei and three superheavy events

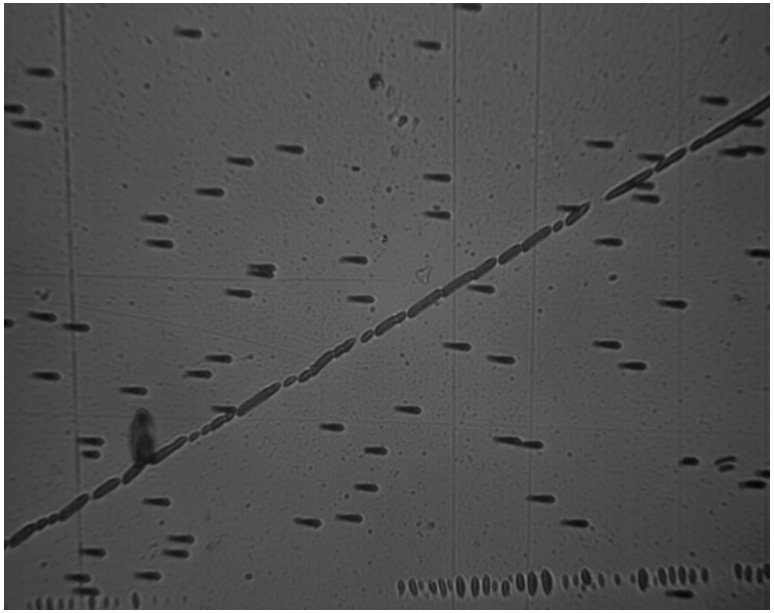


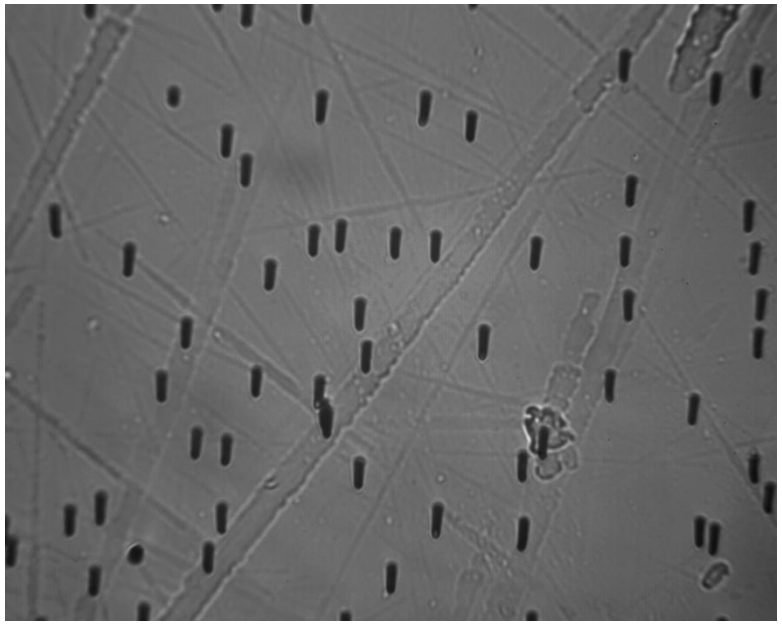
Our experimental points (red cross) and points of satellite experiments. More than 20000 nuclei

2. **Determination of charge and energy of nuclei**

For several years in our laboratory the investigation takes place of the possibility to register fragments of nuclei with solid state detectors

Xe 160 MeV (JINR) Dubna





•Glass КНФС-3

Indian mica

This method is continuation of that used in olivine investigation

Connection: Track length, etching rate => Charge, energy

Several samples were exposed with three nuclei

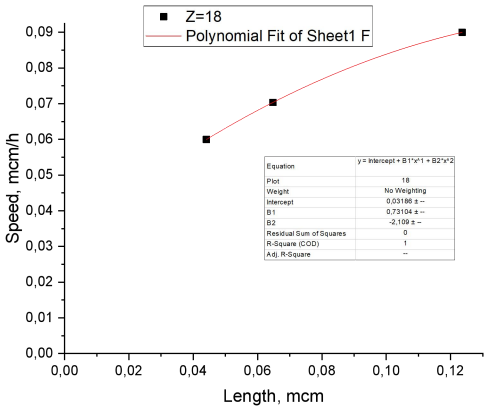
and now they are in processing

==========

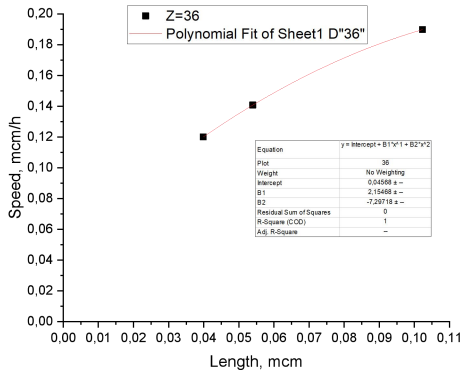
=> The model experiment was carried out

The SRIM calculations of L(Z,E)+our results about V(Z,E)

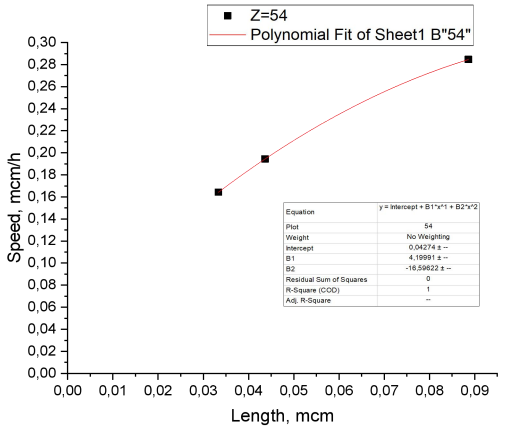
Ar



Kr



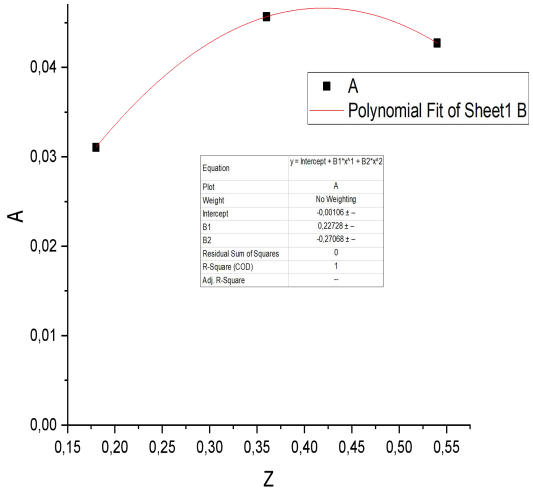
Xe

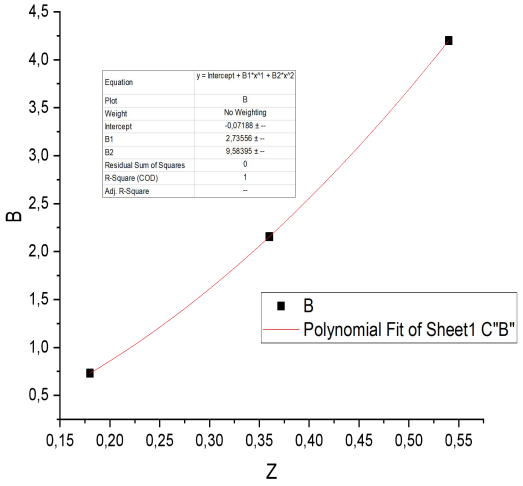


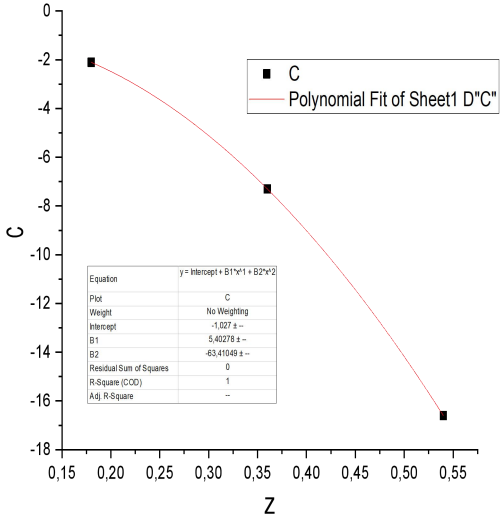
Approximating function: $V=A(Z)+B(Z)*L+C(Z)*L*L$

Parameters A, B, C depend on Z

The Approximation of the A, B and C coefficients







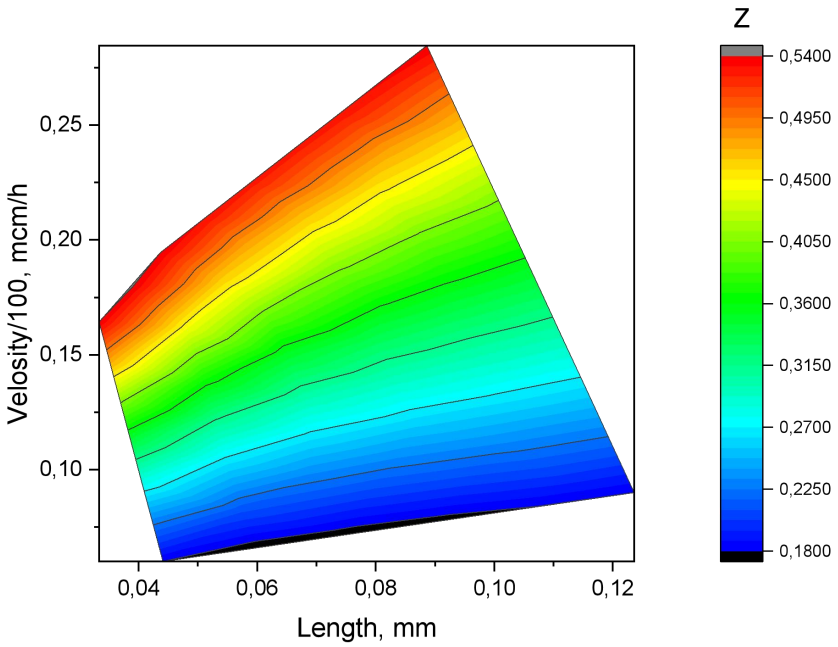
A(Z)

B(Z)

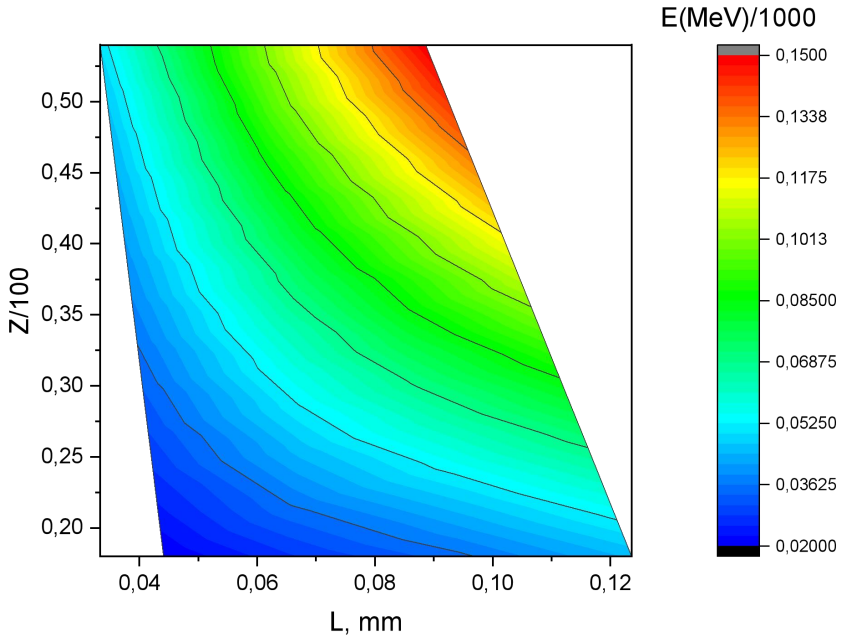
C(Z)

The Functions V(L,Z) and E(L,Z)

The extension of the dependences to the entire region



V(L,Z)



E(L,Z)

Comparison values of charge and energy (true and derived by algorithm)

L, мм	V/100, мкм/ч	Z/100		Энергия E, Мэв/1000	
		Реальный	Оценка	Реальная	Оценка
0,05421	0,2207	0,54	0,537375	0,09	0,08932
0,07664	0,266	0,54	0,536125	0,13	0,1286
0,03847	**0,1522**	**0,46**	**0,45875**	**0,05**	**0,04972**
0,05796	**0,1923**	**0,46**	**0,45875**	**0,08**	**0,07884**
0,05397	0,1416	0,36	0,360125	0,055	0,05437
0,06898	0,1596	0,36	0,3584375	0,07	0,06902
0,05223	**0,09877**	**0,26**	**0,2656875**	**0,0375**	**0,03658**
0,08268	**0,1205**	**0,26**	**0,260125**	**0,055**	**0,05409**
0,06476	0,07047	0,18	0,1816875	0,0275	0,02787
0,09656	0,08312	0,18	0,1804375	0,0375	0,03783

The precision: $Z < 0,5\%$, $E \sim 1,5\%$

3. **Stability at high temperature of nuclei tracks in solid-detectors**

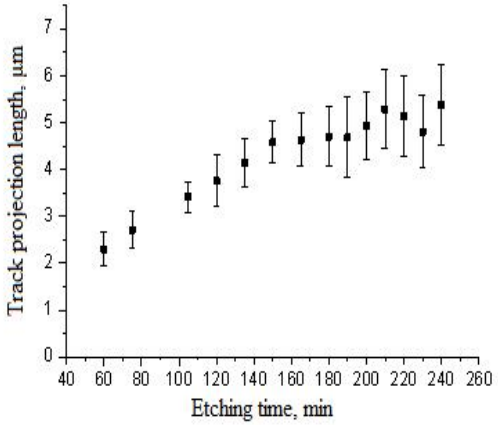
Such conditions arise in experiments on synthesis of superheavy elements.

The aim of our investigation is to find material which is capable to work at this conditions

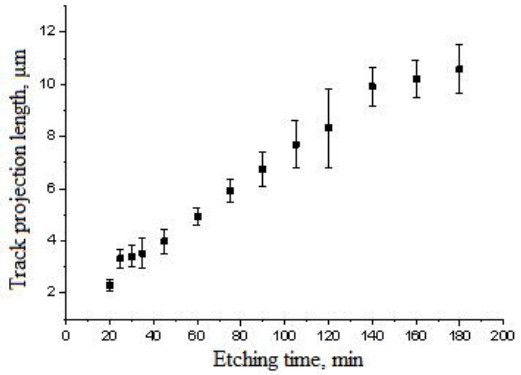
We considered several kinds of glasses and minerals

which were annealing at 500 degrees after irradiation

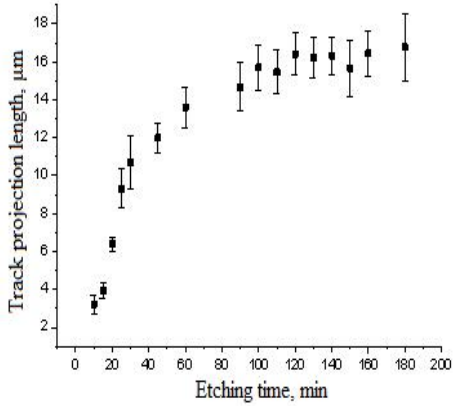
The result of etching of КУ-2 glass



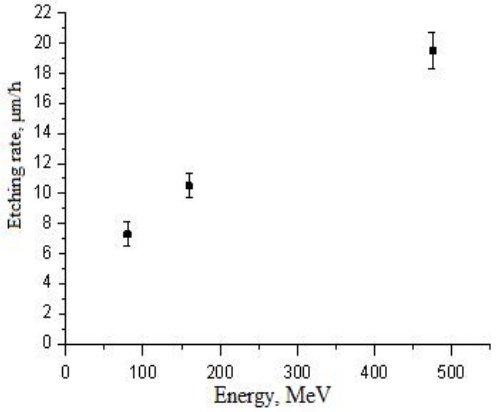
80 MeV



160 MeV



475 MeV

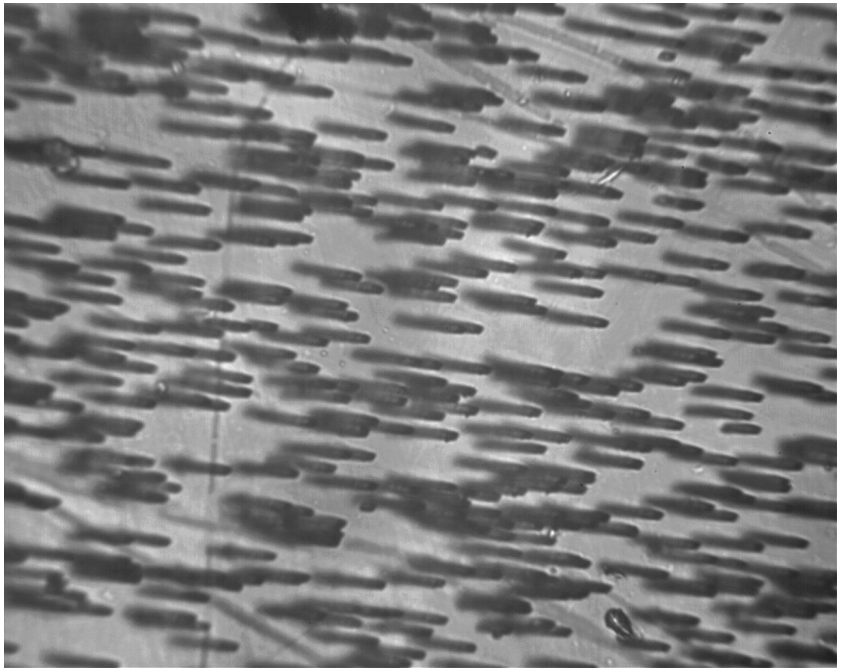


The dependence of the etching rate on energy

The classification of the solid-state detector by stability to temperature

- 1 The tracks disappear (C48-3, fluoroflogopite)
- 2 The tracks are kept but change their characteristics (КУ-2, КНФС-3, SELG)
- 3 The tracks are retained their characteristics (Indian mica)

Indian mica irradiated by Bi of 670 MeV



Normal conditions

Annealing during 3 hours
at 500 degrees

Conclusions

1. An algorithm was designed to build the charge spectrum of galactic nuclei.

2. The improved algorithm is proposed that shows the dependence of the track length the etching rate of charge and energy. It works enough well in the model experiment.

3. Several materials were checked. The material for work on the synthesis of superheavy elements is proposed.The Indian mica keeps nuclei tracks even at the temperature 500 degrees.

Thank you for your attention!