ON THE CHARGE OF QUODONS

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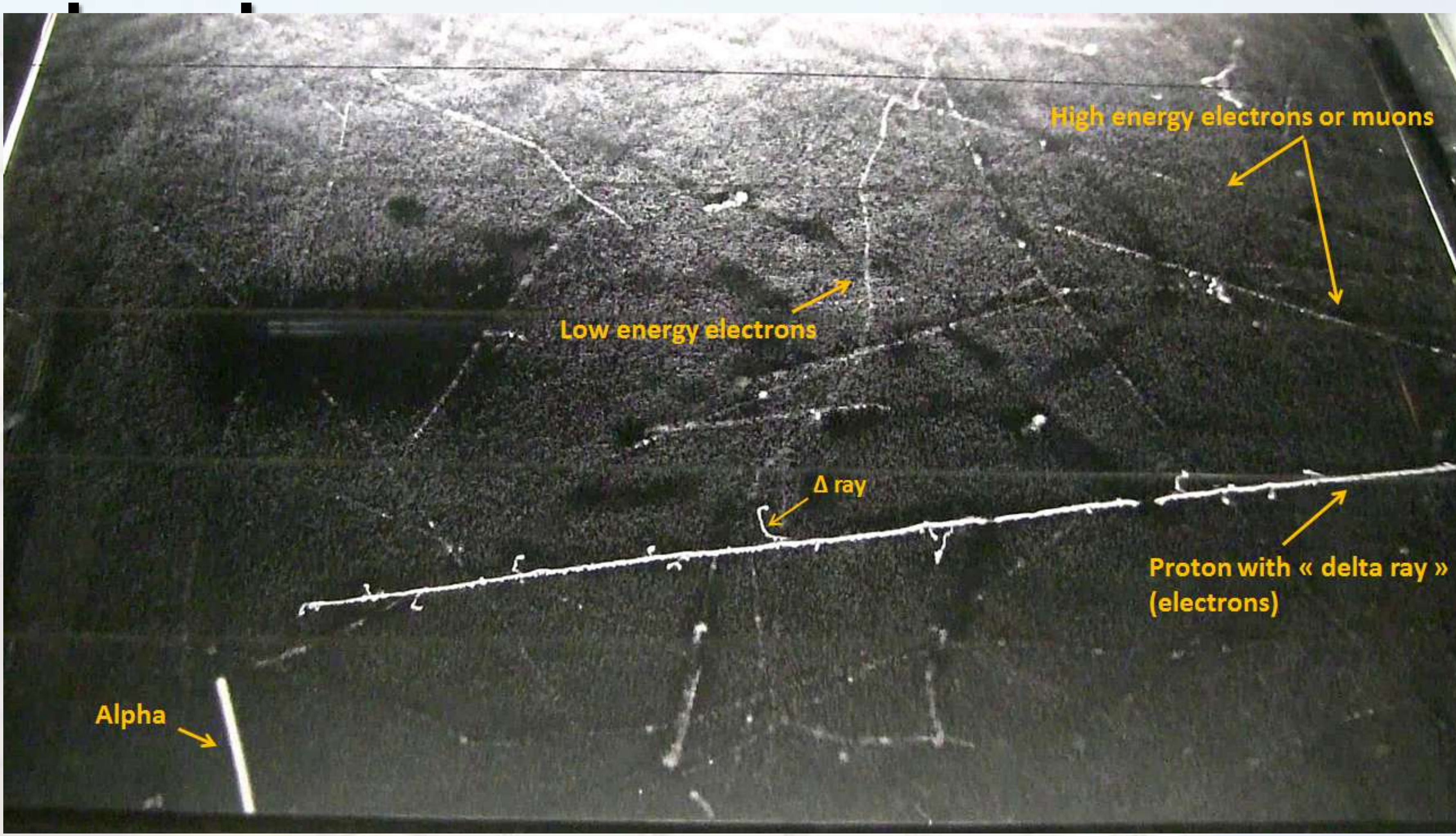
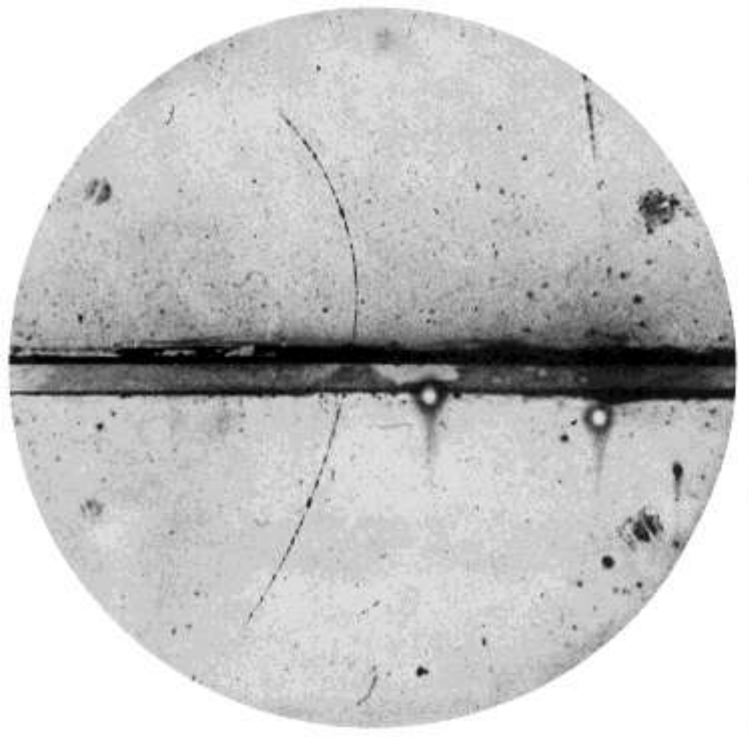
Workshop “Discrete Breathers in Crystals”
Institute for Metal Superplasticity Problems, RAS
Ufa, Russia, September 21-25, 2015.

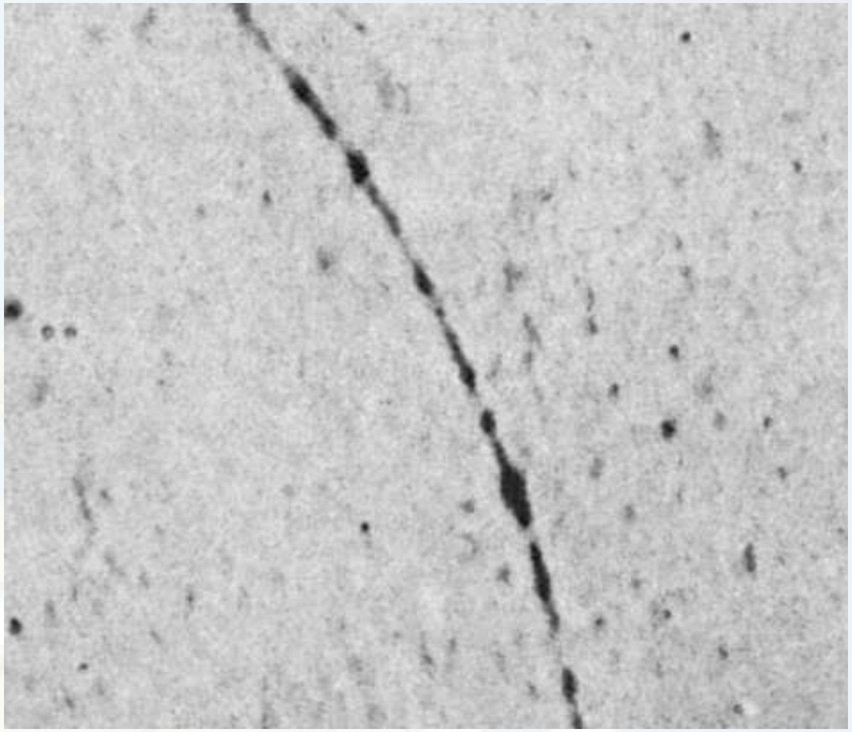
Nuclear particle in a diffusion cloud



- **45x45cm** Image taken in the Pic du Midi at 2877m in a Phywe PJ45, (2014)

First positron identified, Anderson 1932





Positron passing across 6mm lead plate
Diameter 26 cm
Cloud chamber, 63 MeV

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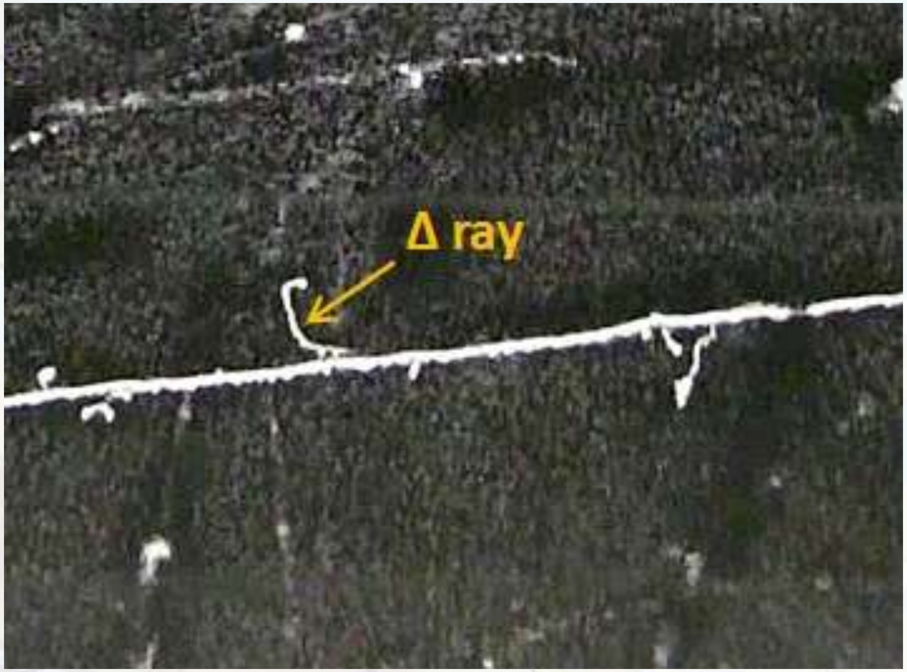
CD Anderson, The positive electron, Phys. Rev. 43 (1933) 491

Nuclear particle in a diffusion cloud chamber



- Supersaturated water (or methanol) vapor
- Charged swift particles act as centers for water droplet formation
- The alcohol vapor condenses around ion trails

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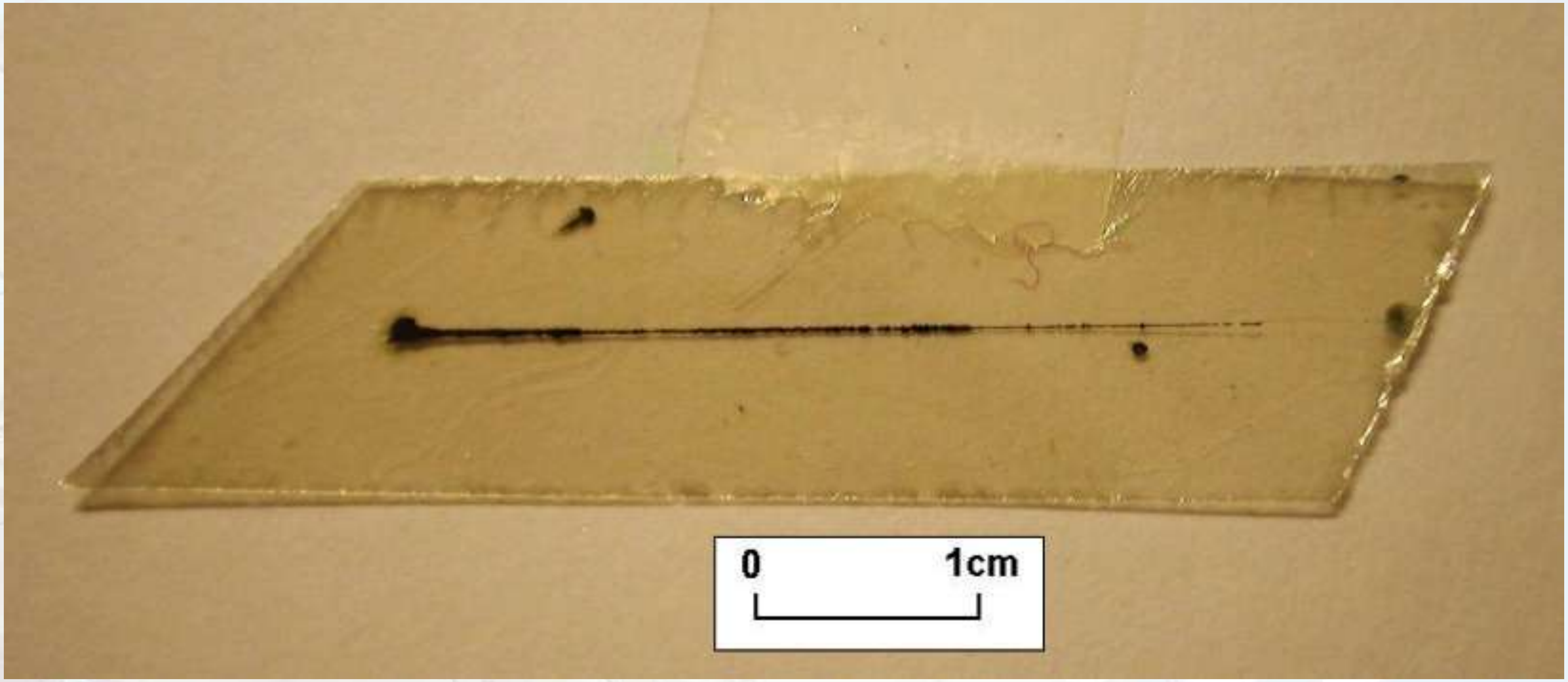
Tracks in mica



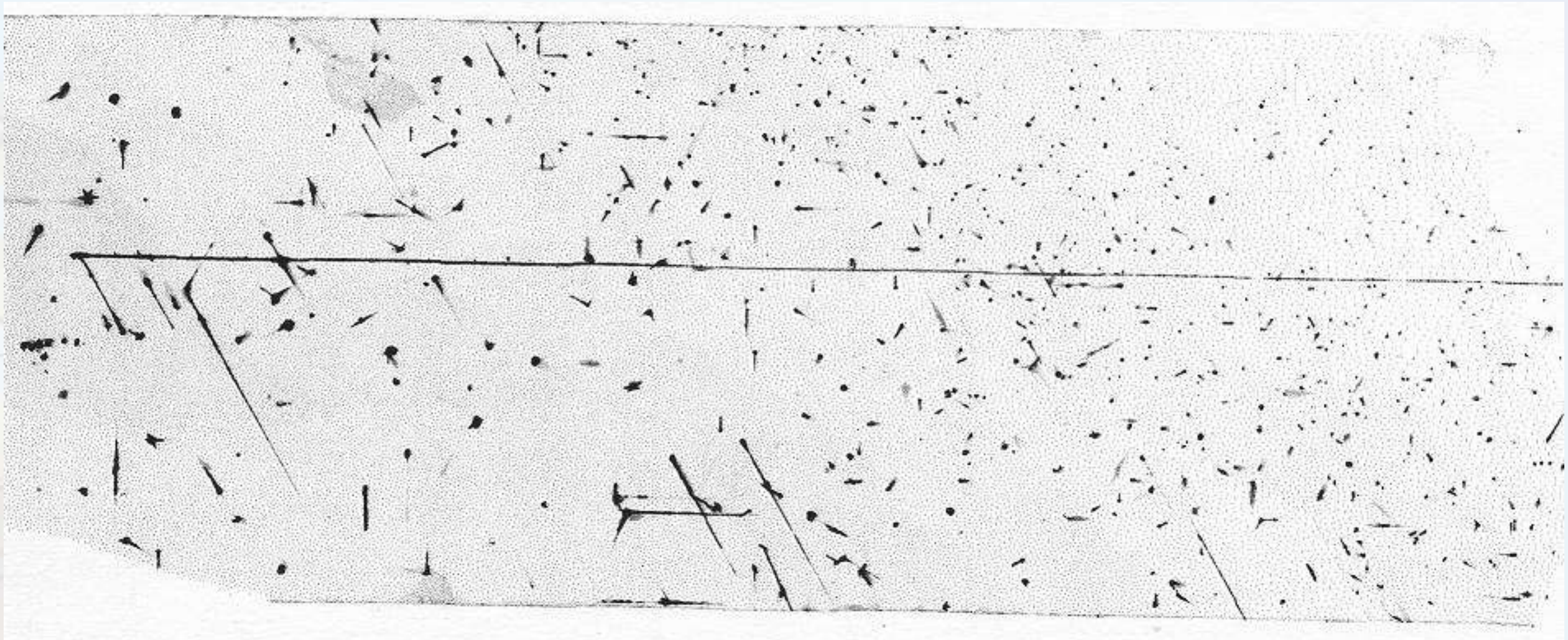
- Positron track produced in the decay of K^{40} with 0.5 MeV.
- 3 per second per cm^3
- Tracks are Fe oxides, magnetite

- FM Russell, From Nature 1967, Nature 216, 907 ; 217 , 51 (1967) and many more

More positrons tracks

FM Russell, From Nature 1967, Nature 216, 907 ; 217 , 51 (1967) and many more

Positron tracks in mica muscovite



- Produced in the decay of K^{40} with 0.5 MeV.
- 3 per second per cm^3
- Tracks are Fe oxides, magnetite

F.M. Russell, Phys. Lett. B 25, 298 (1967); Nature 216, 907 (1967); Nature 217, 51 (1967); Phys. Lett. A 130, 489 (1988); Nucl. Tracks. Rad. Meas. 15, 41 (1988).

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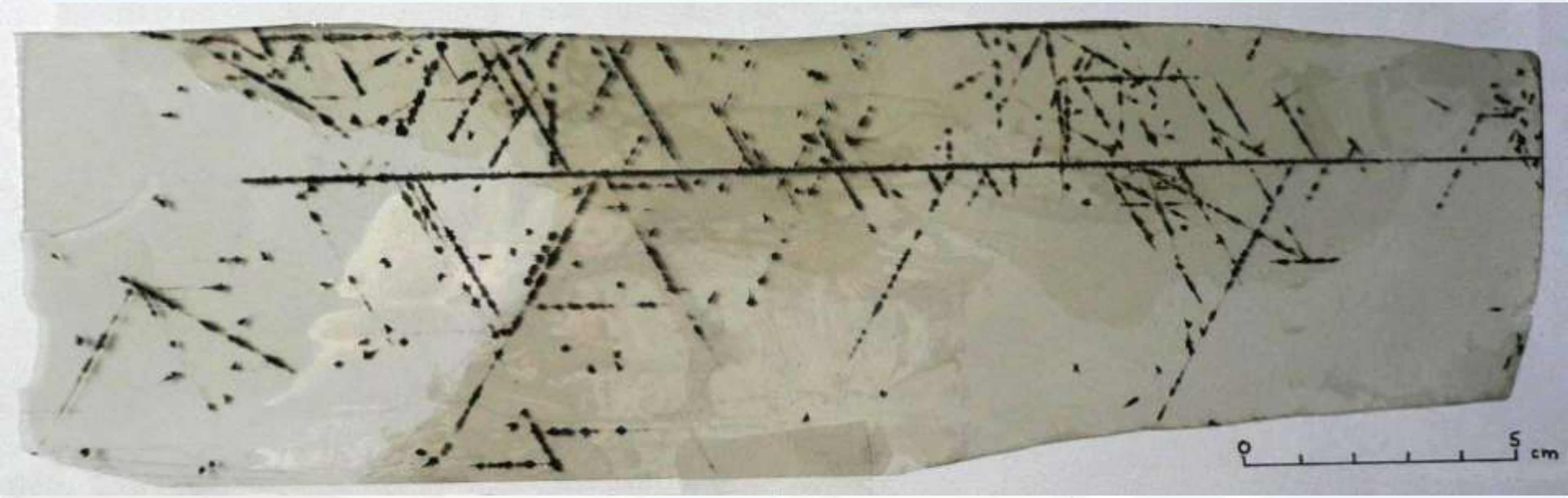
Review: FM Russell, Tracks in Mica, 50 years later. In Quodons in Mica, JFR Archilla et al, eds, Springer (2015)

Quodons: quasi one-dimensional excitations of the lattice in mica muscovite



Tracks: magnetite Fe_3O_4

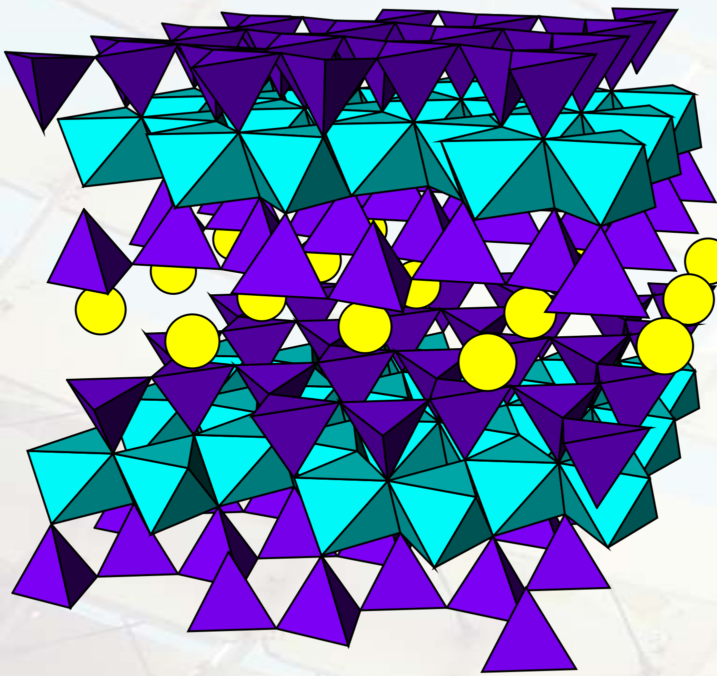
Causes

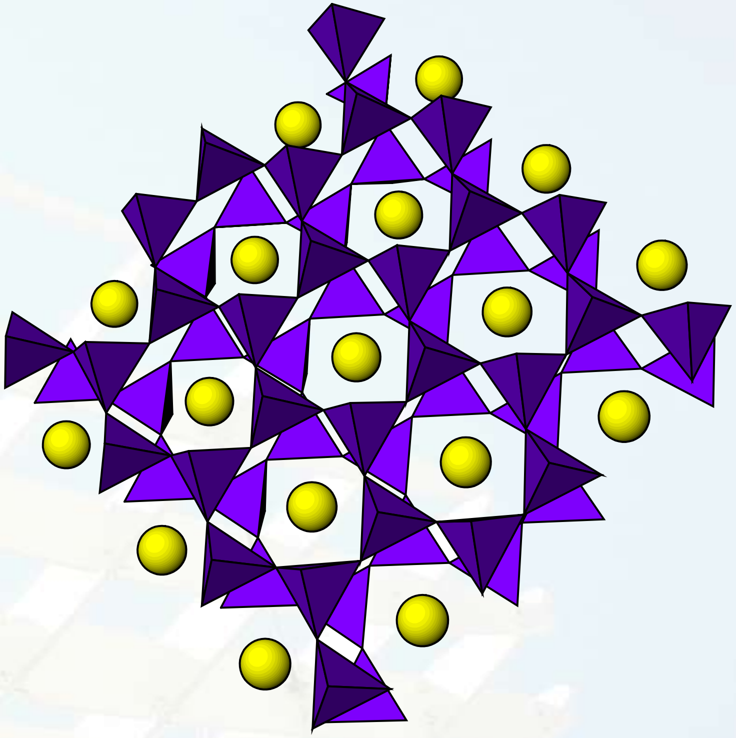
- 0.1% Swift particles
    - antimuons: after neutrino interaction
    - Positrons: decay of 40K
    - Protons
- 99.9% Most in lattice closed packed directions

Anharmonic lattice excitations?

Mica muscovite. Cation layers

$K_2[Si_6Al_2]^{IV}[Al_4]^{VI}O_{20}(OH)_4$



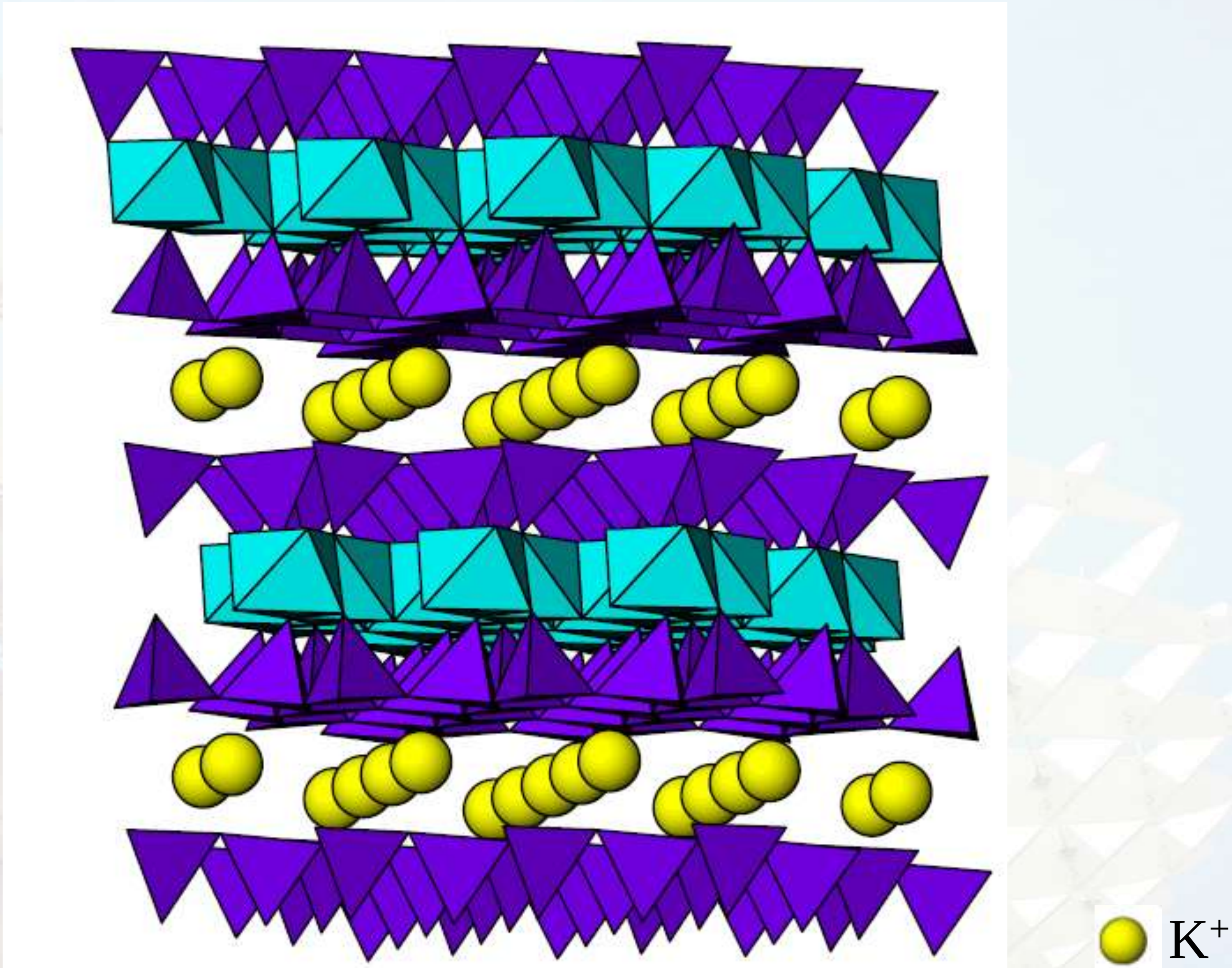


$K_2[Si_6Al_2]^{IV}[Al_4]^{VI}O_{20}(OH)_4$

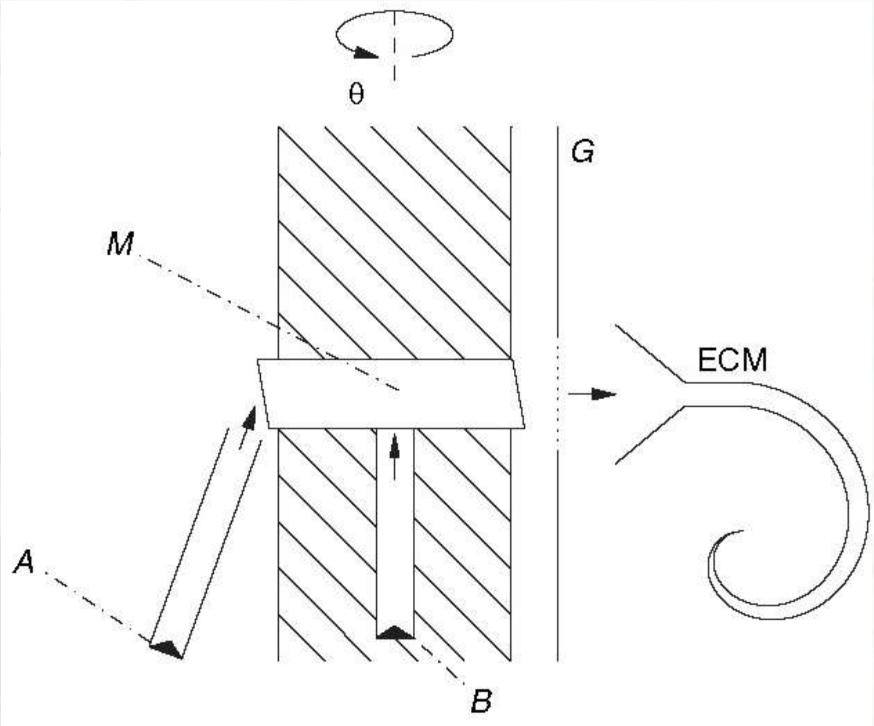
K^+

K^+ : 2D lattice of repulsive particles

Rows of ions within the K layers



Experimental evidence of travelling excitations in mica muscovite



Trajectories were along lattice directions within the K^+ layer

Surface binding energy of ejected atoms unknown: typical values 3-8 eV

- Russell, F.M., Eilbeck, J.C. (2007). Evidence for moving breathers in a layered crystal insulator at 300K. *Europhysics Letters* 78, 1004, 1-5.

Quodons: what kind of lattice excitation?

-Not phonons:

-too low energy with respect to thermal one

-Spread because frequency is in the phonon banc

-Breathers?

-Internal oscillation

-Higher energy

-Frequency outside the phonon bands

-Kinks?

-No internal oscillation

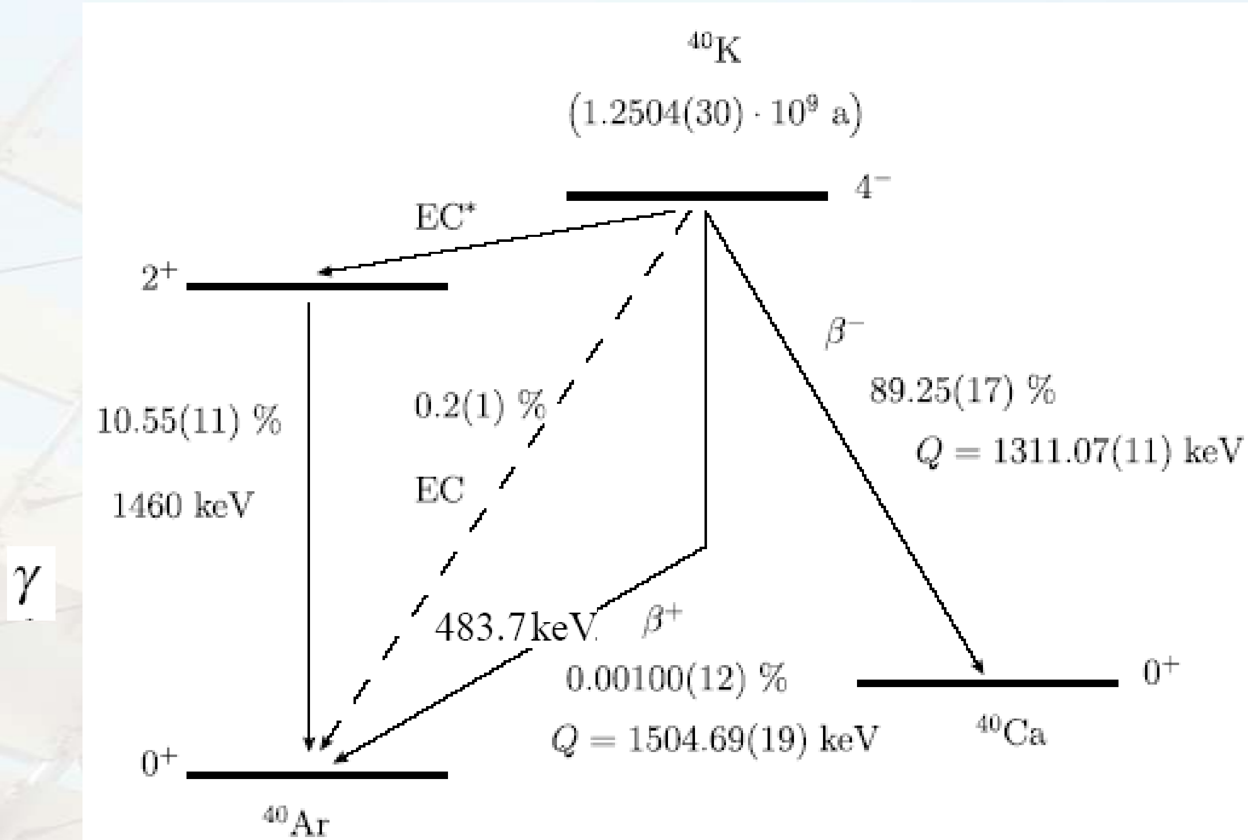
-Supersonic

-High energy

-Other?

- Peakons, compactons, polarons, solelectrons…?

What about charge? K-40 decay modes



Final ion: Ar^+ Ar Ca^{++}

Ar^{++} (CE 0.001%)

EC: electron capture from the shell. CE: conversion electron.

From: Pradler, J., Singh, B., Yavin, I.: Phys. Lett. B 720(2013) 399

K-40 decay modes (energy and charge)

Decay	β^-	EC1	EC1+CE[1]	EC2[2]	β^+
Intensity	89.25%	10.55%	0.001%	0.2%	0.001%
T (keV)	1311.07	1460	1460	1504.69	483.7
Emitted charged particle	e^-		e^-	e^-	e^+
Recoil from	$\nu+e^-$	γ	e^-	ν	$\nu+e^+$
Max Recoil (eV)	42	29.2^M	49.7^M	31.1^M	10
Daugther ion (A=40)	Ca^{++}	Ar^+	Ar^{++}	Ar^{++}	Ar
Max V (Km/s)	14.4	12^M	15.7^M	12.2^M	7
Ionization of daughter (eV)	50.6	27.7	40.8	40.8	15.8
Δq (e)	+1	0	+1	+1	-1

[1] Subset of EC1 when the gamma is delivered to a shell electron; ^{M} Monocromatic
[2] Direct decay to Ar ground state, recoil from neutrino emission; 3 KeV Auger e^-
EC: electron capture; CE: conversion electron; T: energy available excluding rest masses
Ionization energy of K^+ 31.6 eV

Some facts about dark tracks (magnetite)

- Swift particles recorded: positrons, antimuons, protons

- All with positive charge

-Quodon tracks are dark (magnetite)

- 90% of the K-40 decay leave behind a positive charge

- There are also many black dots

- Swift particles and positrons tracks have similar thickness

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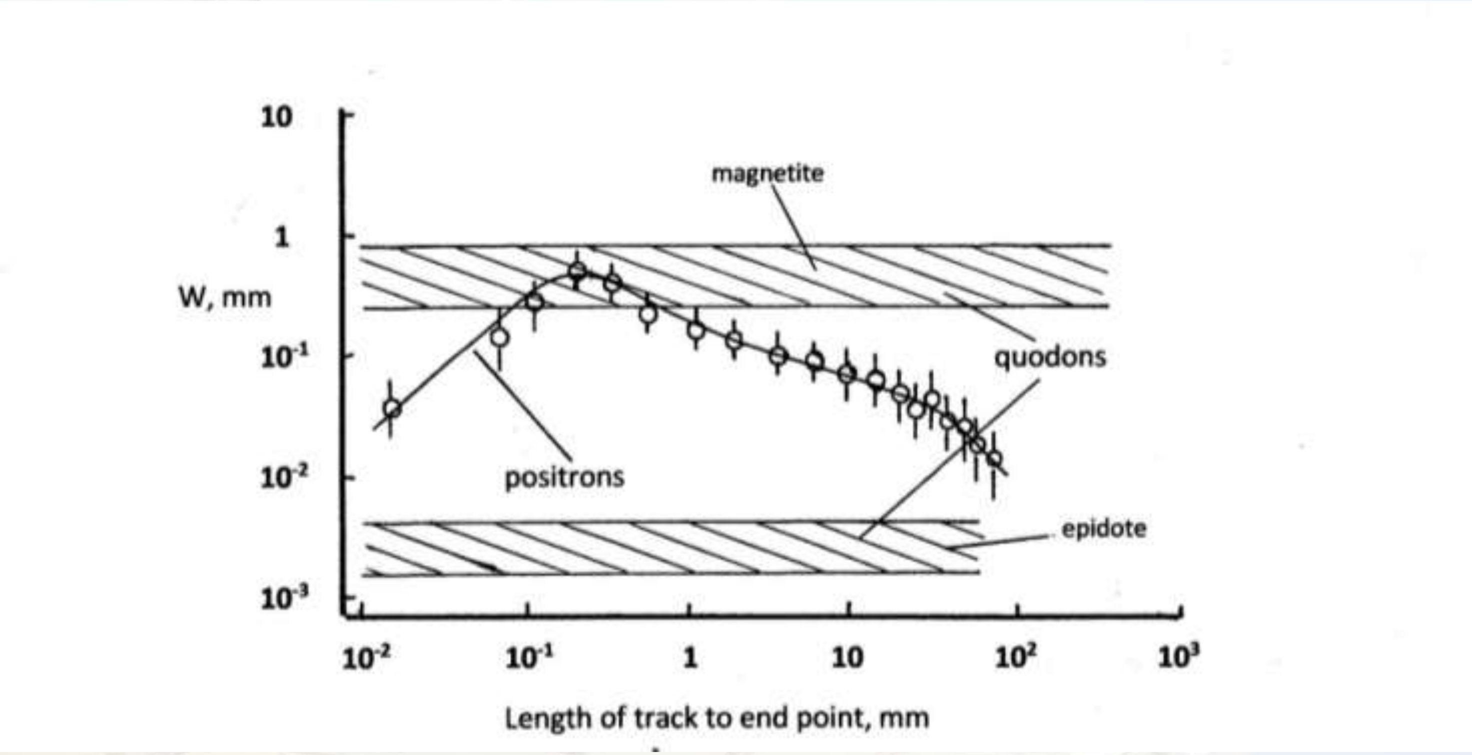
Tracks of positrons and quodons

- Positrons tracks have similar thickness when the positron is about to stop at near sonic speed



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FM Russell (2015), arXiv:1505.03185

Epidote tracks

-There are some faint tracks of a semitransparente material sometimes associated with positron tracks

A positron and the negative quodon produced by the recoil?

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FM Russell (2015)

Hypothesis about quodons

1.-Quodons are localized anharmonic lattice excitations that transport charge.
2.-Positive quodons cause the dark tracks of magnetite seen in mica muscovite
3.-Negative quodons are also produced and they may leave semi-transparent epidote tracks

Crowdions are positive: they should leave a dark track is stable in 2D

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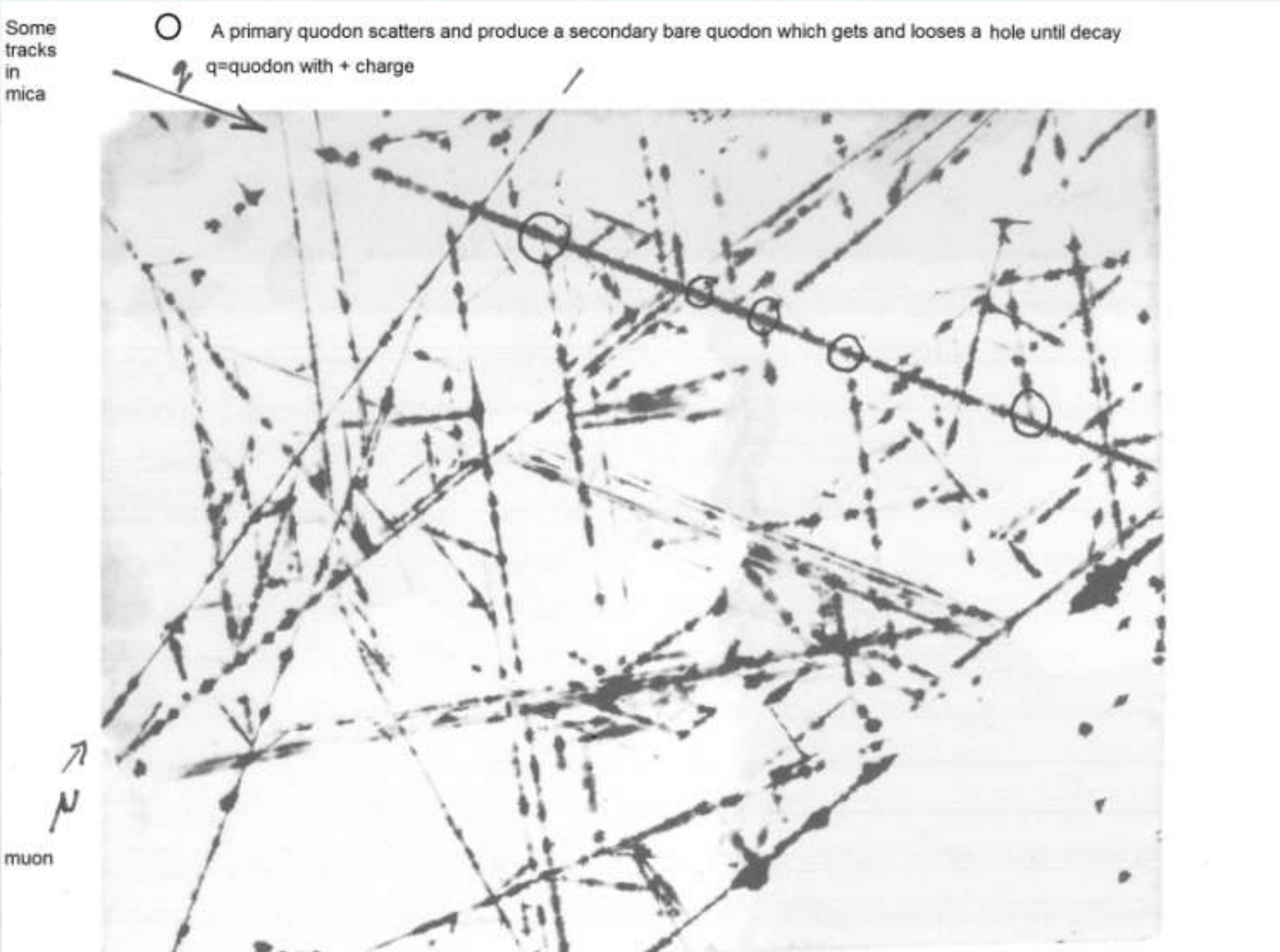
Many new interpretations of tracks



Primary positive quodons, and bare ones

Hypothesis about the lattice

- As K I ionization potential is 4.3 eV, this can be taken as the energy given by the lattice
- The charge of K^{+} is compensated by the lattice
- K^{++} can be considered as a excited positive (q=+1) state with 31. 6-4.3 =27,3 eV
- Other ions with +1 positive charge also have 4.3 eV lattice energy
- Ions with high ionization energy will have a strong tendency to recover their ionization potential energy taking an electron

Table 2 Table of ionization energies (eV) of atoms involved in ^{40}K decay [Lide]

Element/Ionization	I	II	III	IV	V
Ar	15.76	27.63	40.74	59.81	75.02
K	4.34	31.63	45.81	60.91	82.66
Ca	6.11	11.87	50.91	67.27	84.50

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Possible types of charged excitation

-Crowdions (Kinks): Equivalent to a positive K^+ interstitial

- Bi-crowdions, multicrowdions?

- Vacancies: Have a negative charge

- Multivacancies

- Travelling ionization states $K^{++} + K^{+} \rightarrow K^{+} + K^{++}$

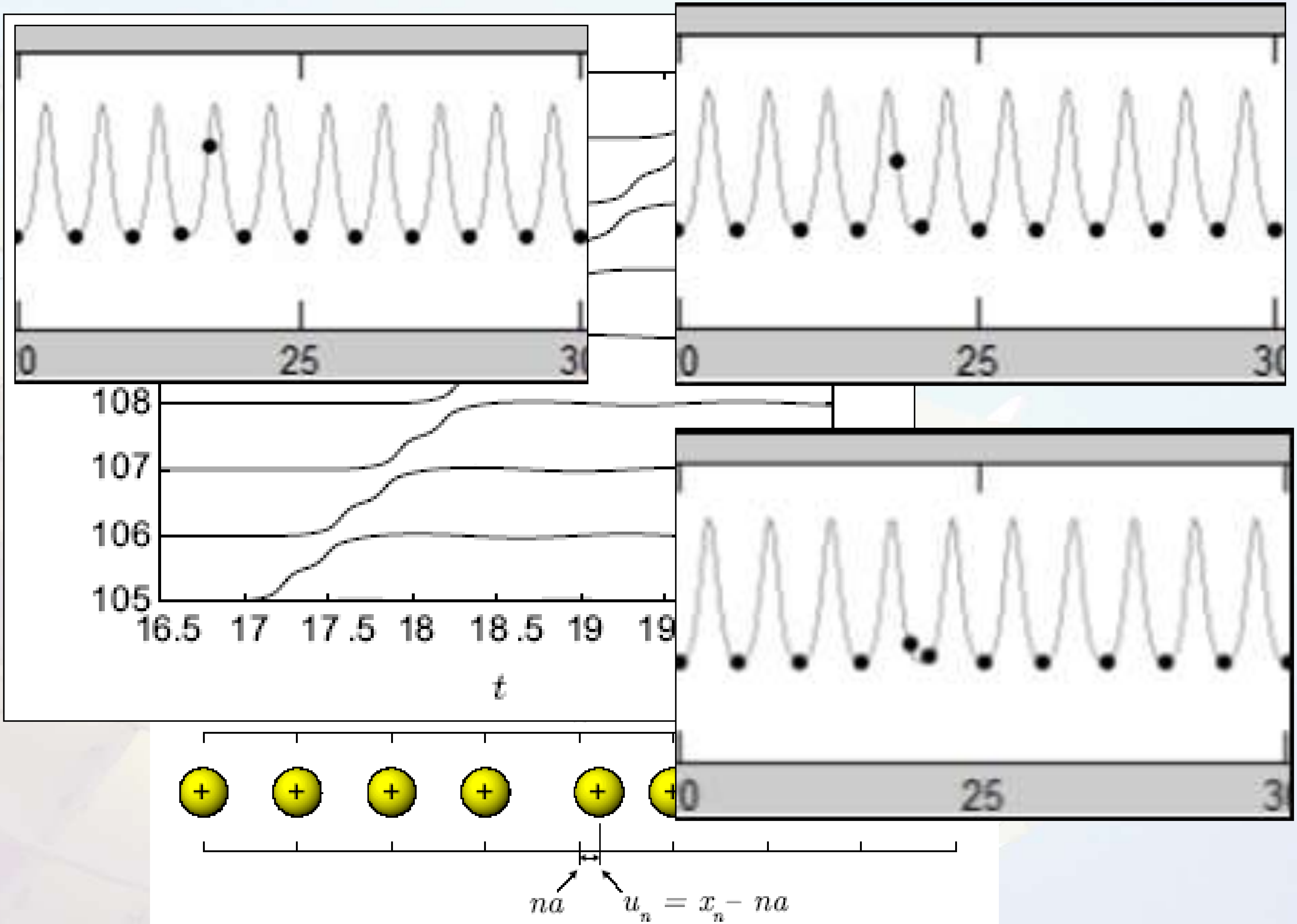
- Other ionization states? $K^{+++} + K^{+} \rightarrow K^{+} + K^{+++}$

-Can a breather trap a charge?

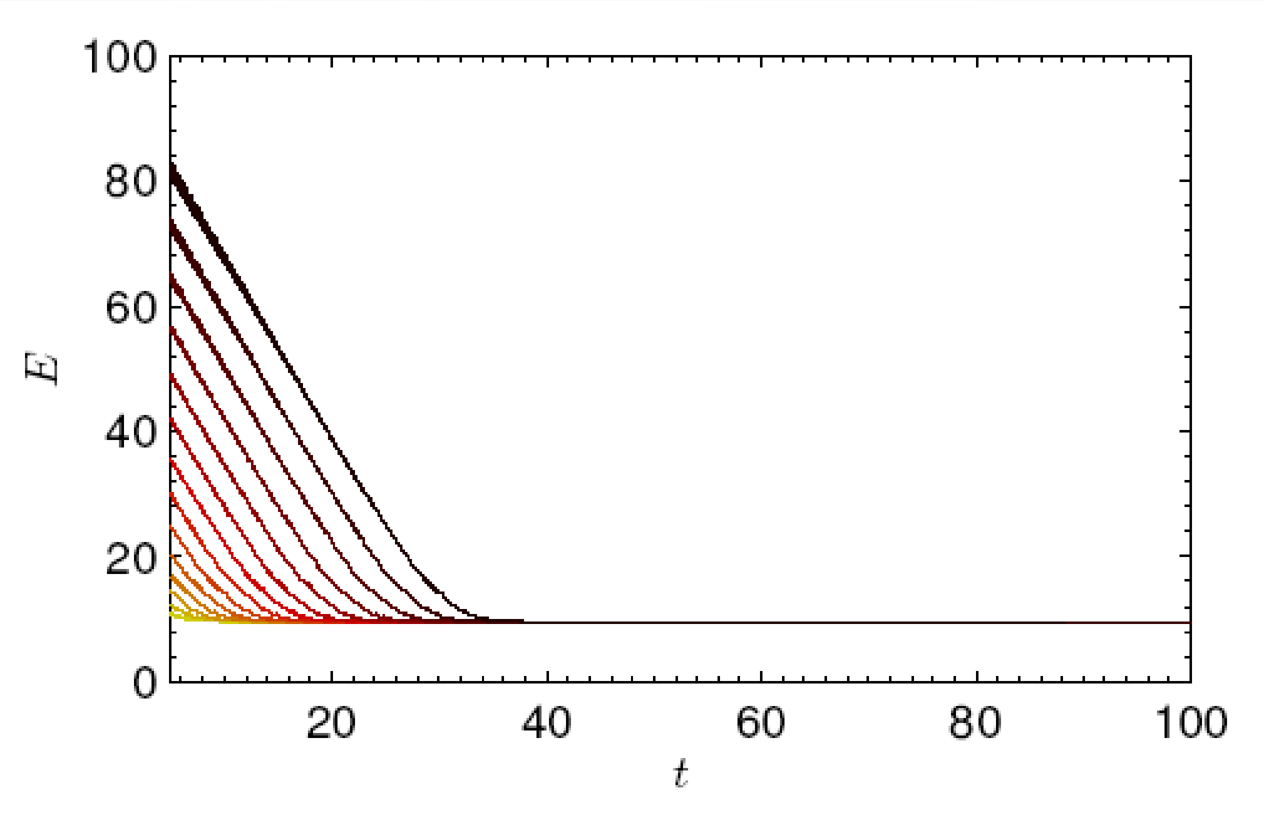
-Can kinks trap charge?

-Can charge be lost and/or recovered?

Sketch of supersonic crowdion



Supersonic crowdion: energy selected by the lattice



$V_c = 2.7387$ (7.2 km/s) $E_k = 9.5$ (26.2 eV)

JFR Archilla, Yu A Kosevich, et al, Ultradiscrete kinks with supersonic speed in a layered crystal with realistic potentials, Phys. Rev. E 91, 022912 (2015)

Supersonic crowdions: long story

-Kosevich, A.M., Kovalev, A.S.: The supersonic motion of a crowdion... Solid State Commun. 12, 763–764 (1973);

-Savin, A.V.: Supersonic regimes of motion of a topological soliton. Sov. Phys. JETP 81(3), 608–613 (1995);

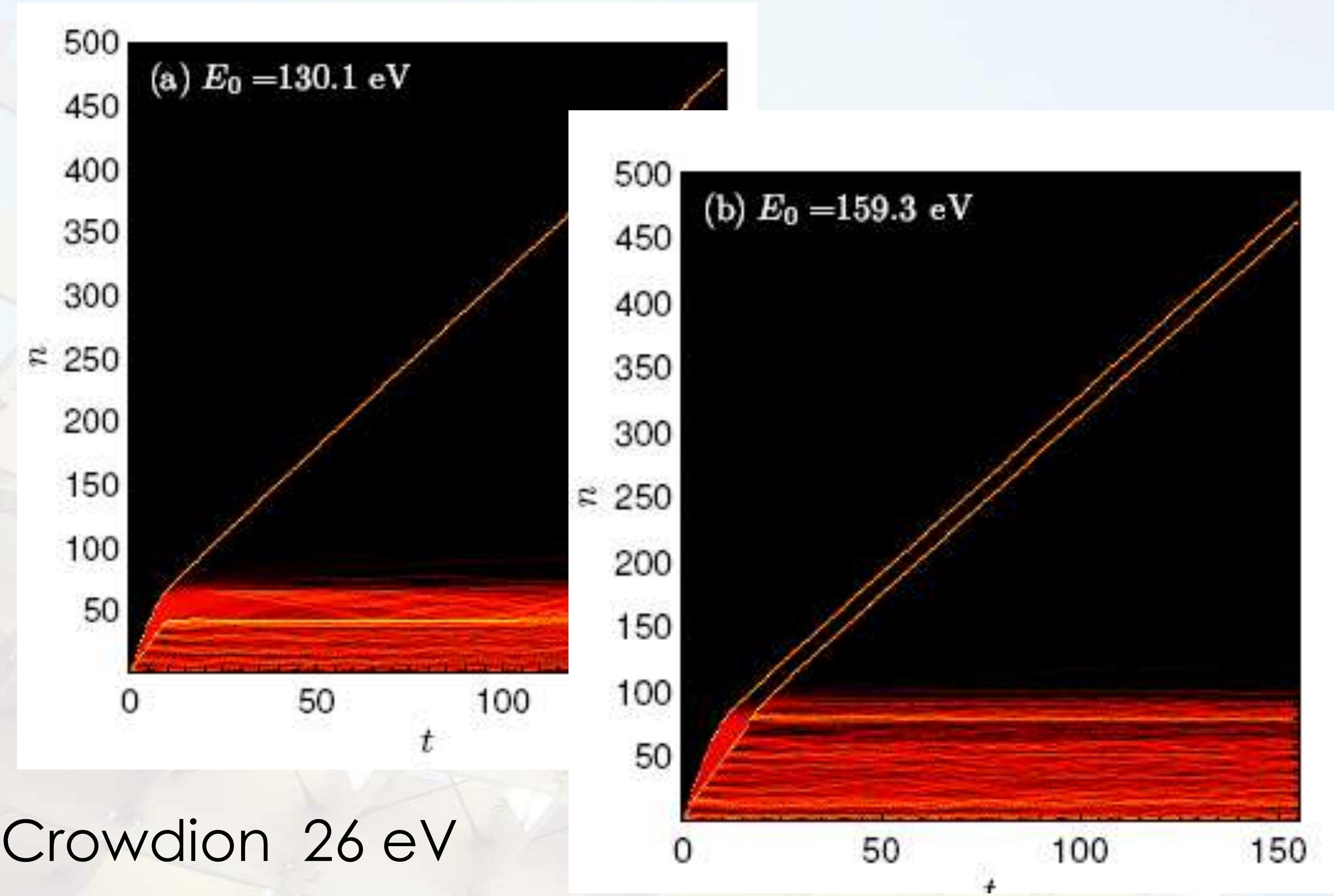
-Zolotaryuk, Y., Eilbeck, J.C., Savin, A.V.: Bound states of lattice solitons and their bifurcations. Physica D 108, 81–91 (1997)

-G. Friesecke and K. Matthies, Atomic-scale localization of high energy solitary waves on lattices, Physica D 171, 211 (2002).

-M. Molerón, A. Leonard, and C. Daraio, Solitary waves in a chain of repelling magnets, J. Appl. Phys. 115, 184901 (2014).

-A.M. Iskandarov, N. N. Medvedev, P. V. Zakharov, S. V. Dmitriev Crowdion mobility and self-focusing in 3D and 2D nickel. Comp. Mat. Sci.., 47:429, 2009.

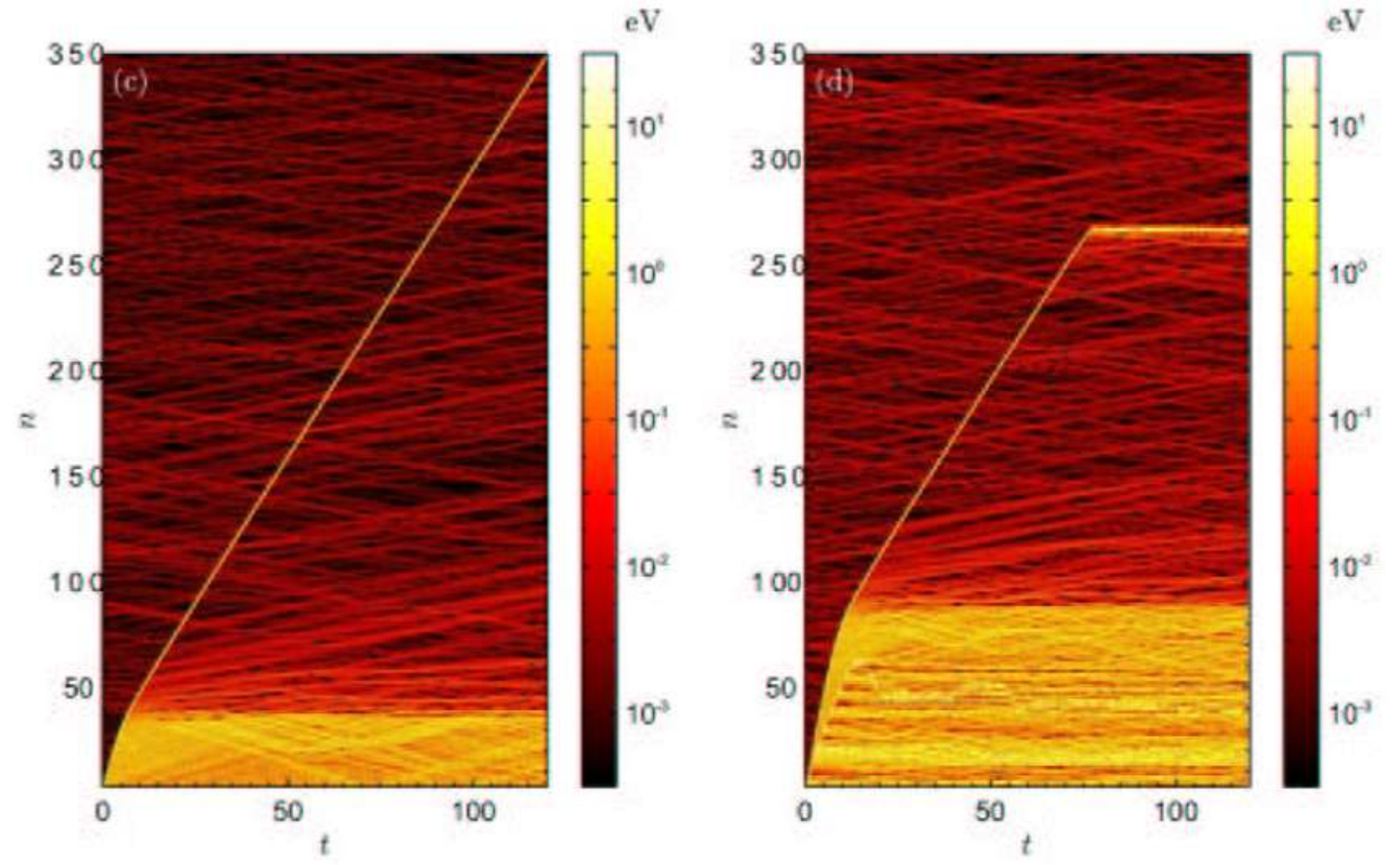
Excess energy: several crowdions



Crowdion 26 eV

JFR Archilla, Yu A Kosevich et al , *A Supersonic Crowdion in Mica:* In Quodons in Mica, Springer (2015) pp. 69-96

Crowdion in thermalized medium



300 K

1000 K

Properties of crowdions in mica (1D)

-Crowdions travel long distances

-The energy of the crowdion 26 eV can be provided by K40 decay (0-50 eV)

-The energy of the crowdion is enough to expel an atom (4-8 eV)

-Crowdions have large energy with respect to thermal one ~1000X

-Crowdions survive to high temperatures 300 K, even 1000 K
- Crowdions transport positive charge

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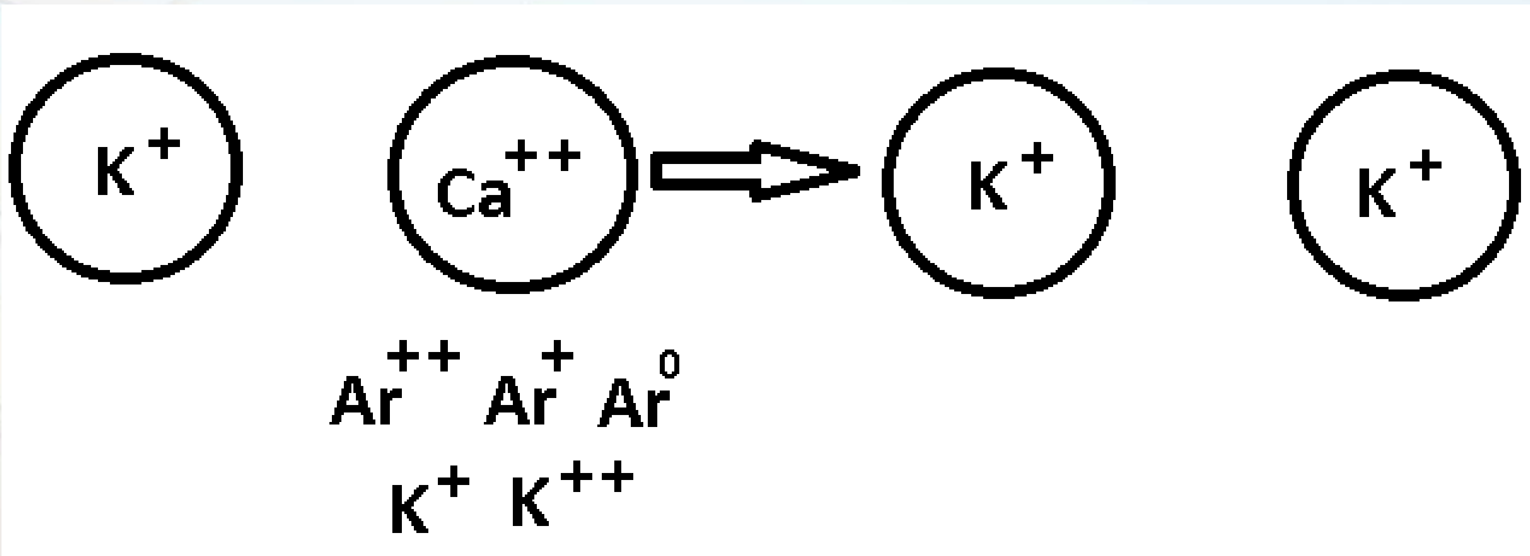
-What will be the properties in 2D?

Inelastic collisions

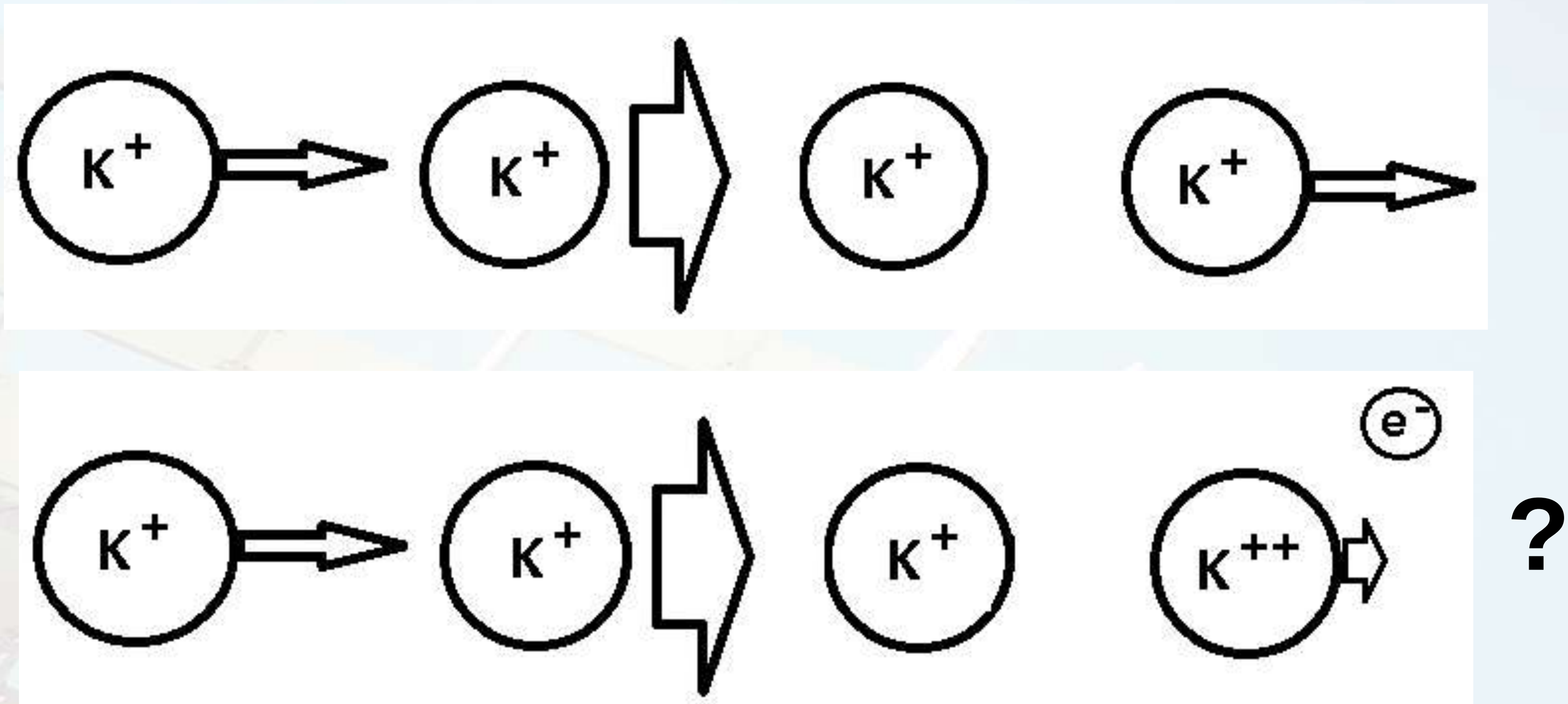


$E_1+Q=E_1'+E_2'$; $p_1=p_1'+p_2'$, with $E=p^2/2m$

Q: difference in potential ionization and lattice energy

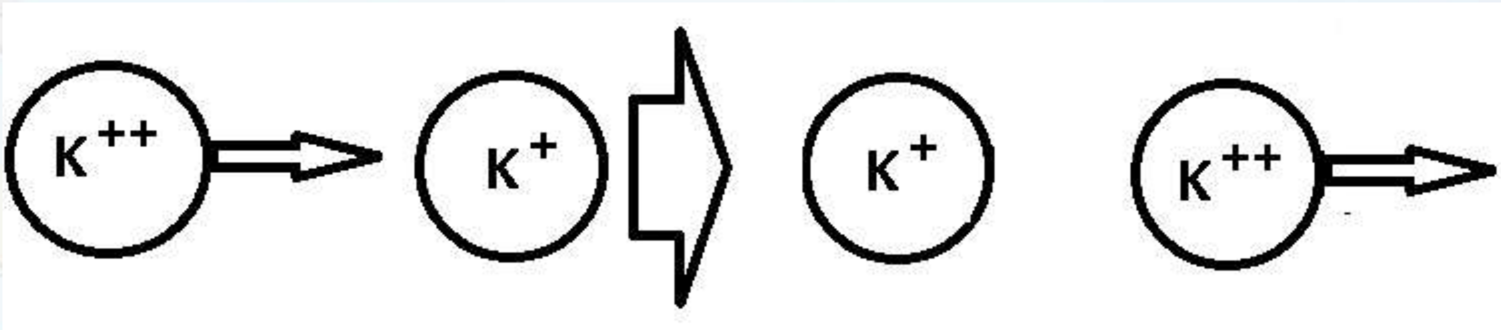
First limitation: $E_1>-2Q$ ($m_1 \sim m_2$, 40~39)

Crowdion stability?



Is it possible ionization to K^{++}?
As Q=31.6 eV
For second ionization E_1>-2Q=63.2eV that cannot be provided by K-40 decay

Travelling charge states?



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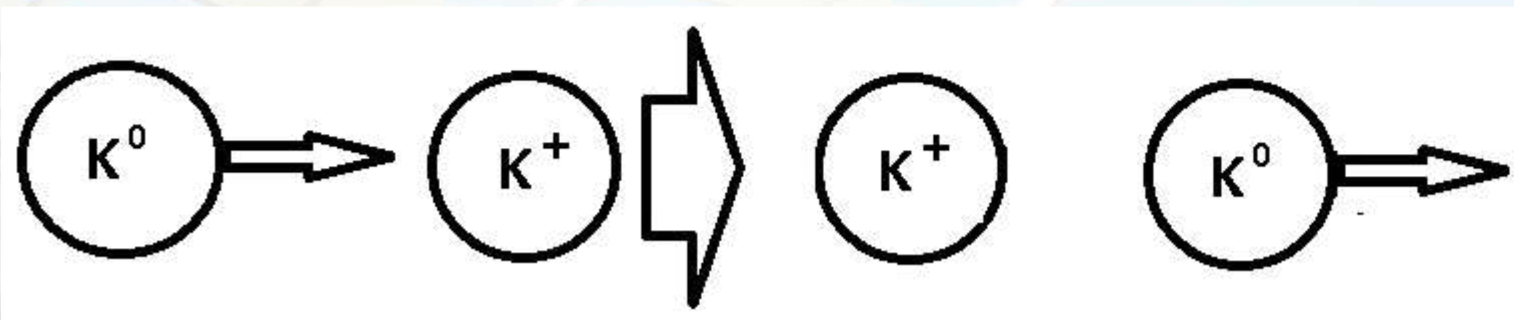

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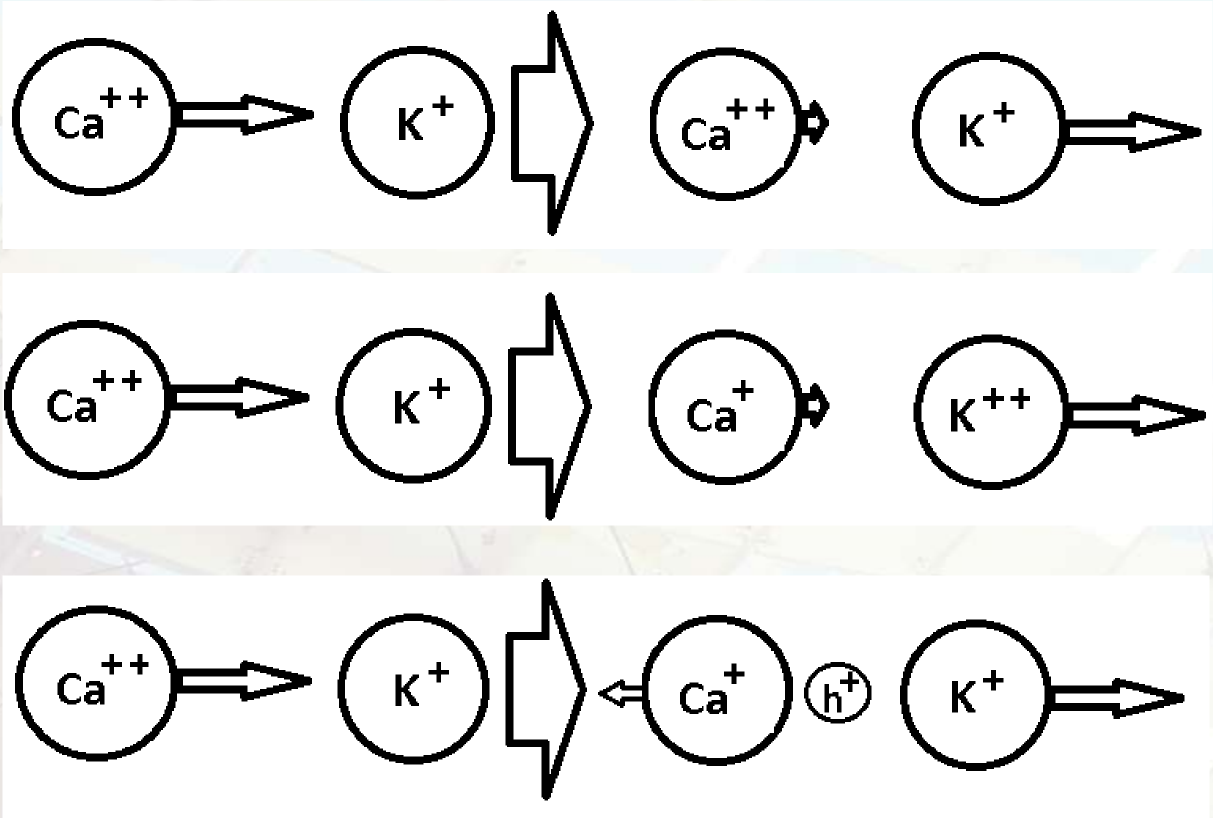
Both are possible

No other ionization states are possible

The second collision (1)

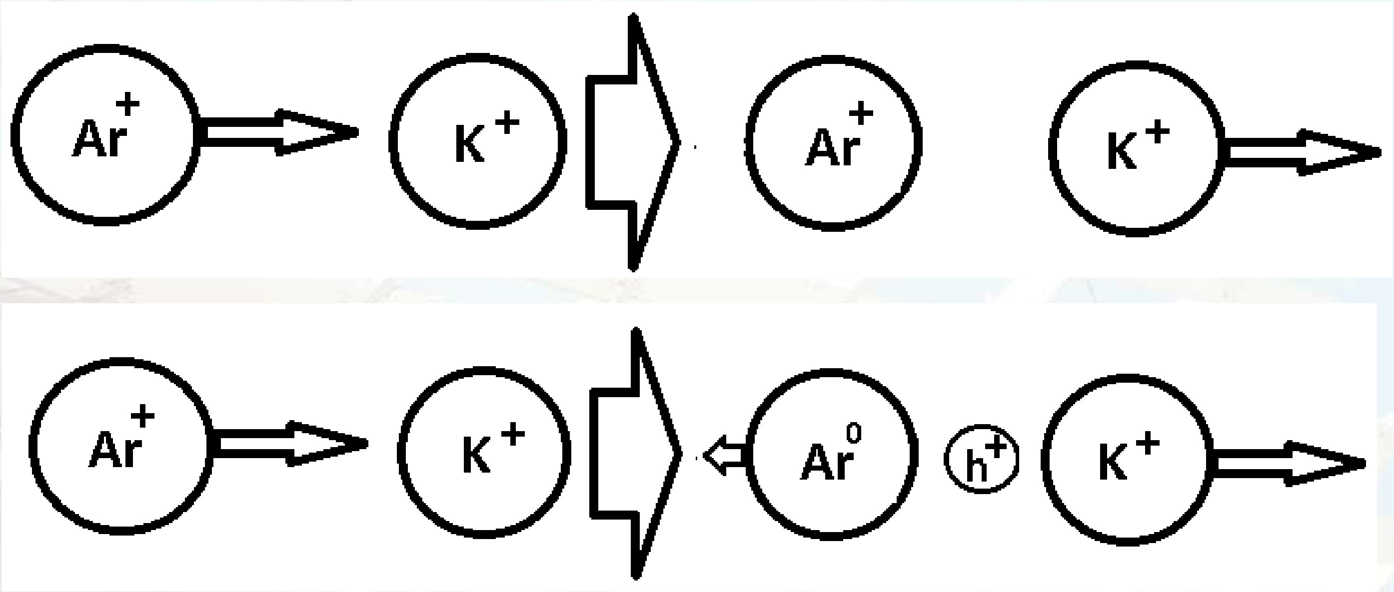
From electron emission : $Ca^{++}+K^{+}$



Crowdion, positive charge state, ILM backwards

The second collision (2)

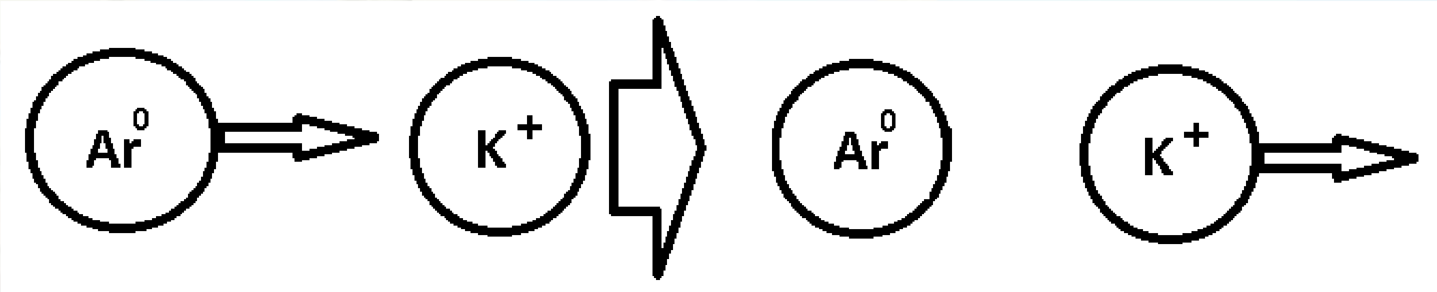
From EC1: Ar^+ (E=29 eV, monochromatic)

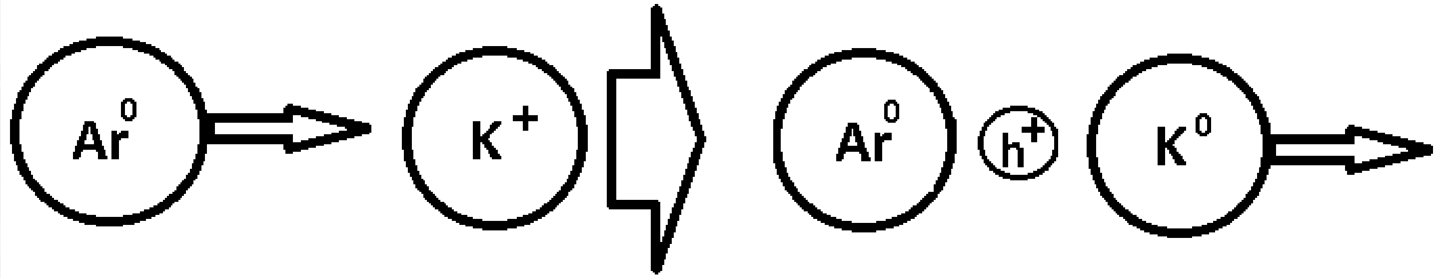


Crowdion, ILM forward, ILM backwards

The second collision (3)

From positron emision Ar^0 (E<15eV)





ILM, crowdion, negative charge state

Conclusions

1.-Dark tracks in mica are produced by positive charge
2.-Epidote tracks are produced by negative charge
3.-Quodons can be positive, negative quodons or bare quodons, with very different range
4.-Quodons can take and loose charge
5.-Crowdions have positive charge and should leave a dark track
6.-Possibly ionization states can travel through the lattice
7.-It is necessary to consider the secondary knocked ions and its outcomes
8.-The identification of the different processes giving rise to quodons have just started but it is very promising

Some bibliography

Ultra-discrete kinks with supersonic speed in a layered crystal with realistic potentials, JFR Archilla, Yu A Kosevich, N Jiménez, VJ Sánchez-Morcillo and LM García-Raffi
Phys. Rev. E 91 (2015) 022912

JFR Archilla, Yu A Kosevich, N Jiménez, VJ Sánchez-Morcillo, LM García-Raffi , *A Supersonic Crowdion in Mica: Ultradiscrete kinks with energy between 40K recoil and transmission sputtering,* In Quodons in Mica: Nonlinear Localized Travelling Excitations in Crystals, J.F.R. Archilla et al, eds, Springer (2015) pp. 69-96

FM Russell, *Tracks in Mica, 50 Years Later: Review of Evidence for Recording the Tracks of Charged Particles and Mobile Lattice Excitations in Muscovite Mica*, In Quodons in Mica, Nonlinear Localized Travelling Excitations in Crystals , J.F.R. Archilla et al, eds, Springer (2015) pp. 3-33

FM Russell, JC Eilbeck, Evidence for moving breathers in a layered crystal insulator at 300 K. Europhys. Lett. **78**, 10004 (2007)

FM Russell, Charge coupling to anharmonic lattice excitations in a layered crystal at 800K, arXiv:1505.03185