

CONTRIBUTION OF DIFFERENT PARTICLES ONBOARD BION-M1 ESTIMATED BY MEANS OF PLASTIC NUCLEAR TRACK DETECTORS

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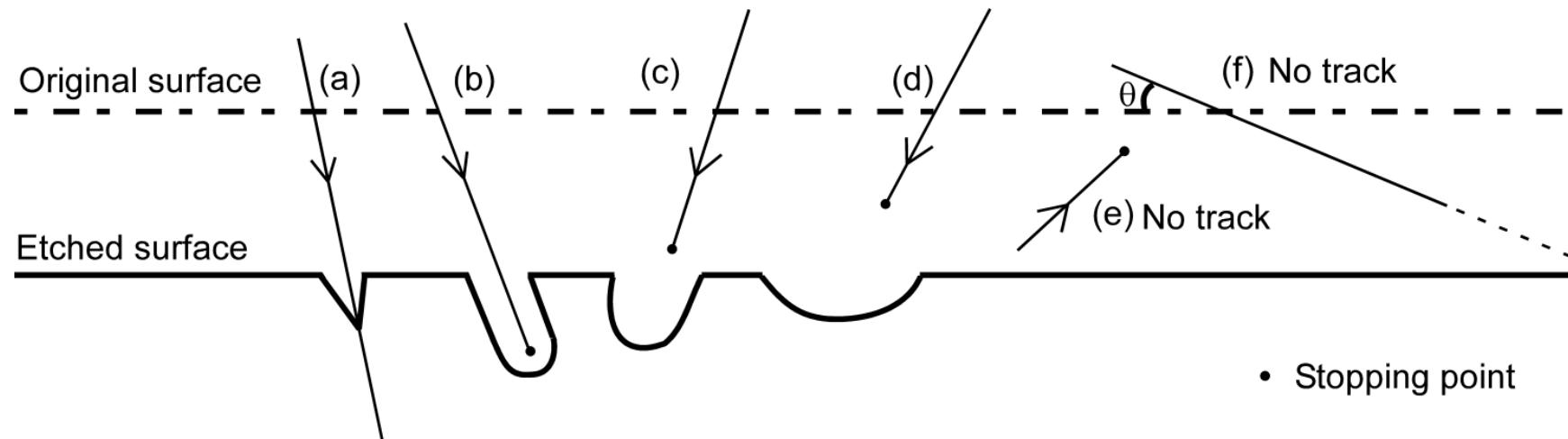
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Cosmic radiation

- very complex (primary high-energy galactic and solar particles, particles trapped in Earth's radiation belts, secondary particles)
- plastic nuclear track detectors (PNTD)
- passive detectors – small weight and dimensions, no need of power supply, easy manipulation ...
- TLD + **PNTD** → total absorbed dose, dose equivalent, quality factor

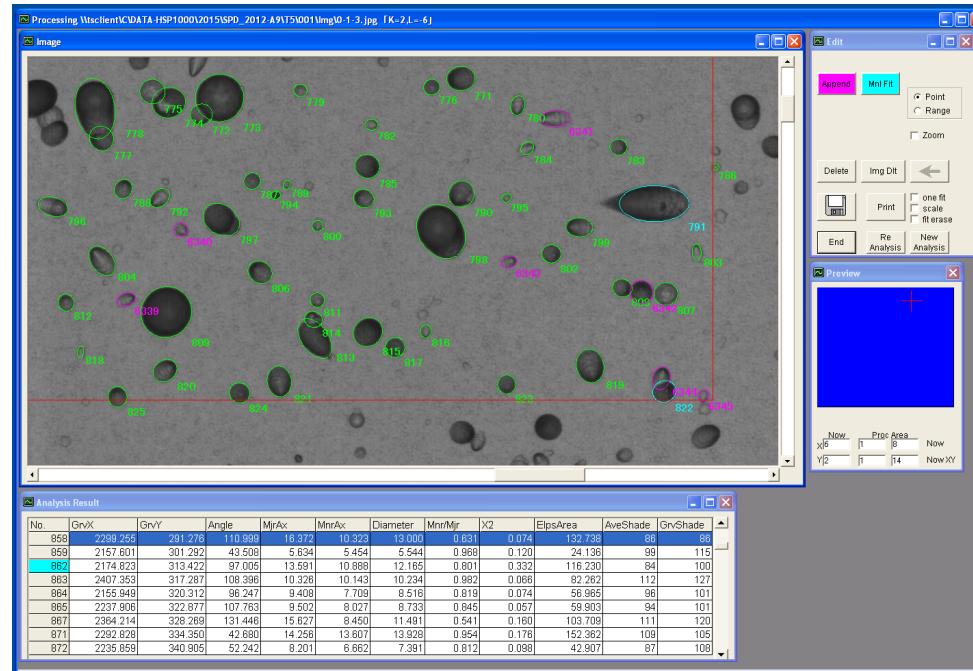
Plastic nuclear track detectors

- separation of different particles (dimensions of tracks → LET, shape of tracks, **range in the material**)
- multiple etching and detailed analysis of paired tracks



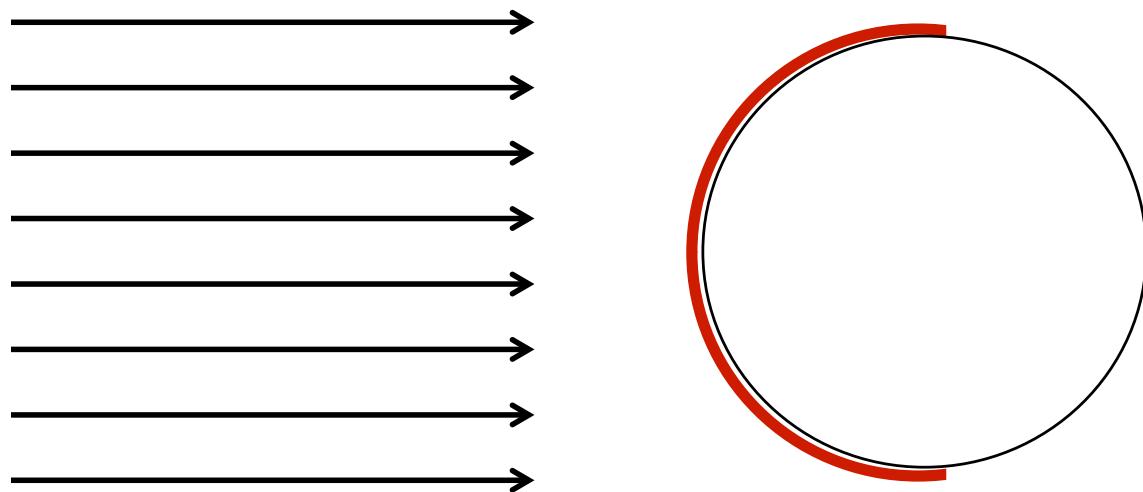
Plastic nuclear track detectors

- Harzlas TD-1 (Nagase Landauer Ltd.), PADC, thickness 0.9 mm
- etching in 5N NaOH at 70°C, usually for 18 h, bulk etch rate about 0.83 µm/h
- calibration at HIMAC (ICCHIBAN) and other heavy ion beams
- semi-automatic analysis (system HSP-1000 SEIKO Precision and software HspFit)
- LET (> 7 keV/µm), absorbed dose, dose equivalent



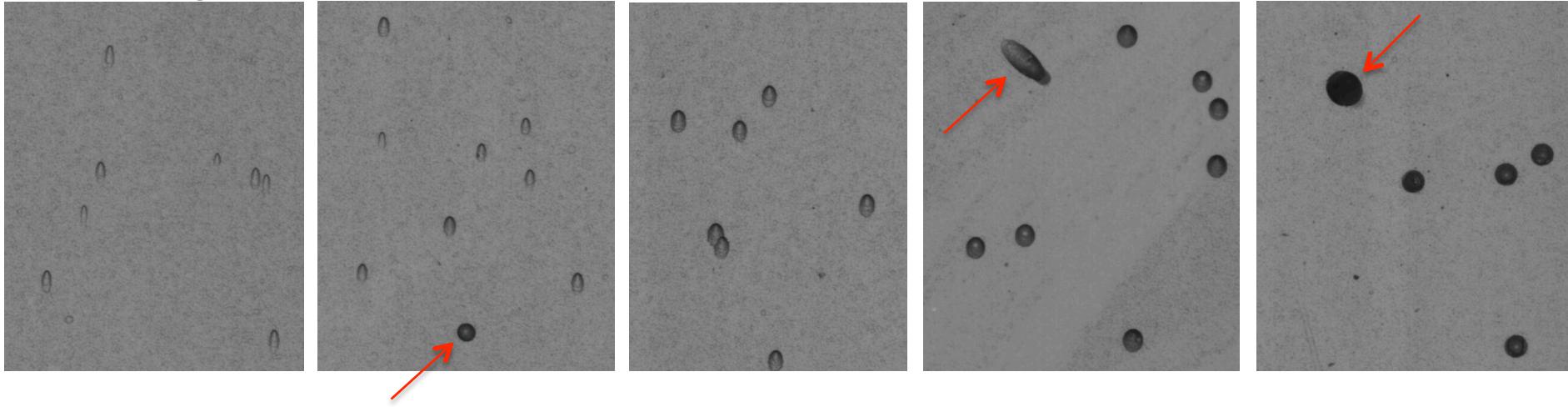
Multiple etching – HIMAC

- tested using detectors irradiated at HIMAC
- Ne 400 MeV/u at HIMAC, different angles
- 18 + 18 hours etching

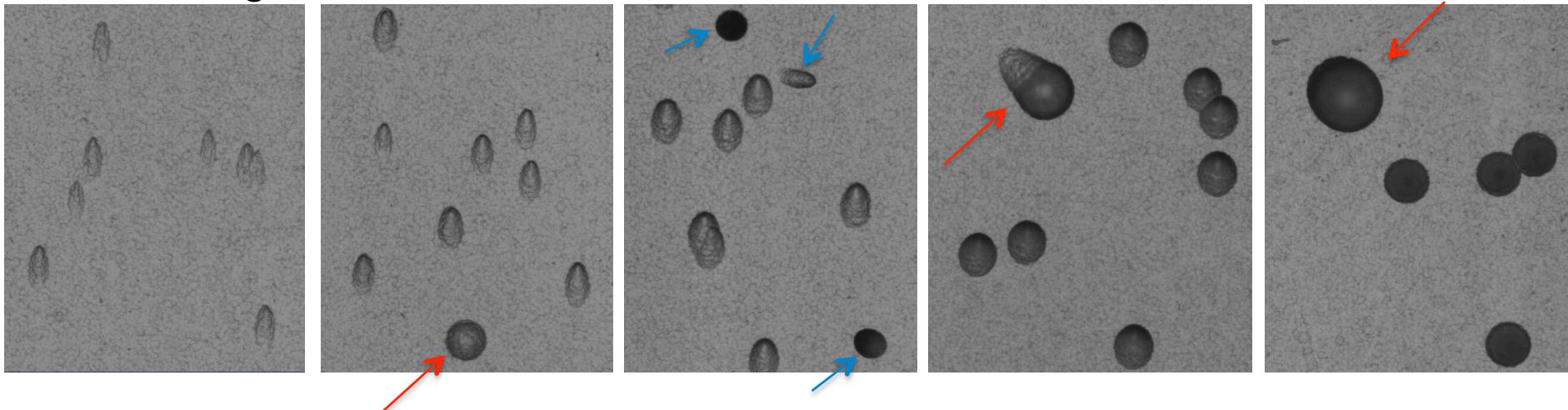


Multiple etching – HIMAC

first etching

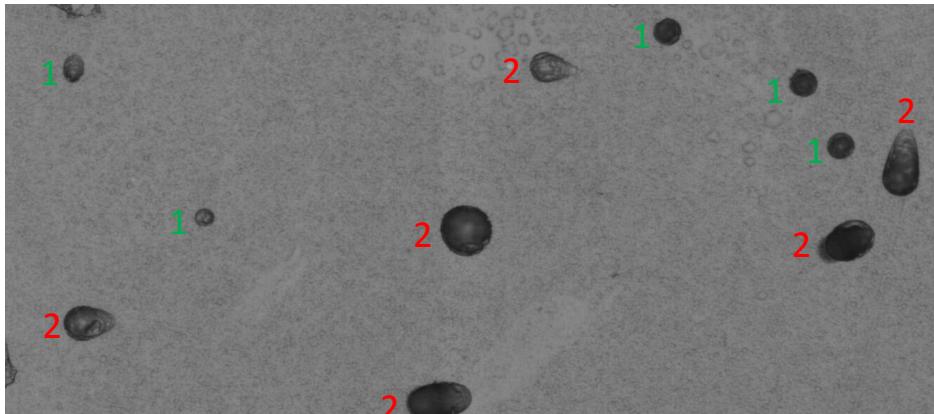


second etching

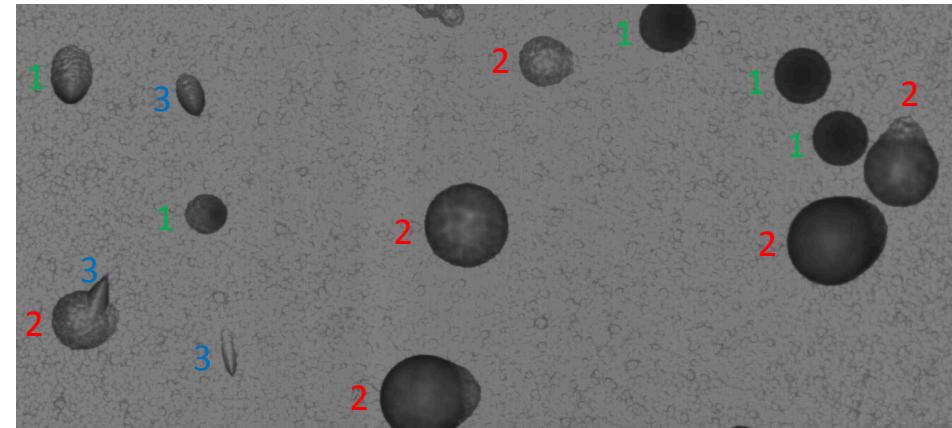


Multiple etching

- 1) primary heavy ions
- 2) short-range particles that become over-etched
- 3) particles created inside the detector



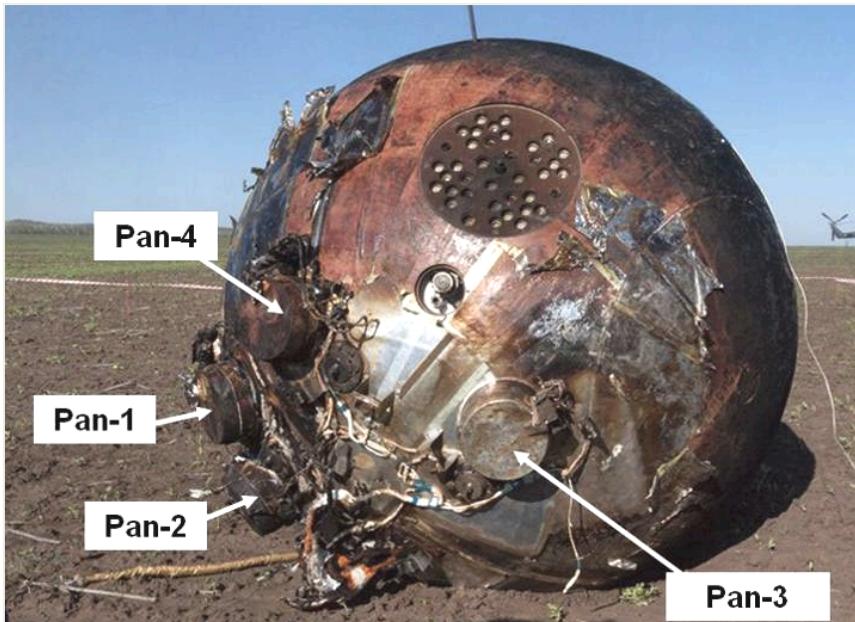
first etching



second etching

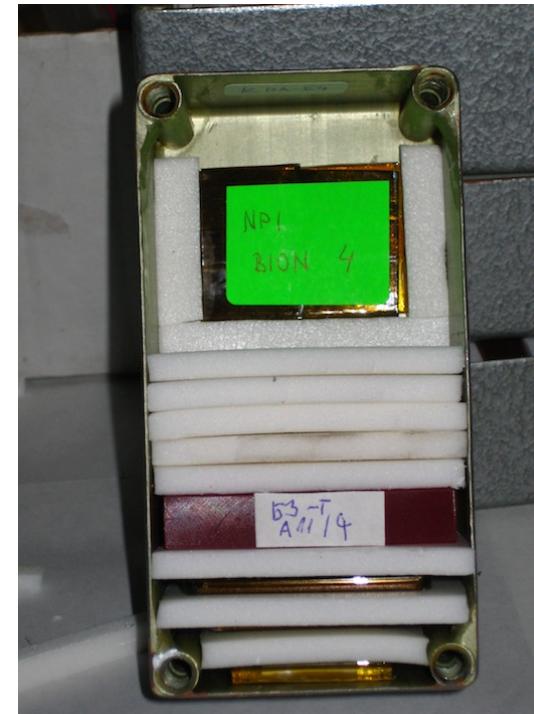
BION-M1

- free-space flyer mission
- altitude 565–585 km, inclination 64,9°
- April 19 – May 19 2013 (30 days)
- biological samples and detector instruments inside (pressurized and controlled temperature) and outside (unpressurized and uncontrolled temperature)



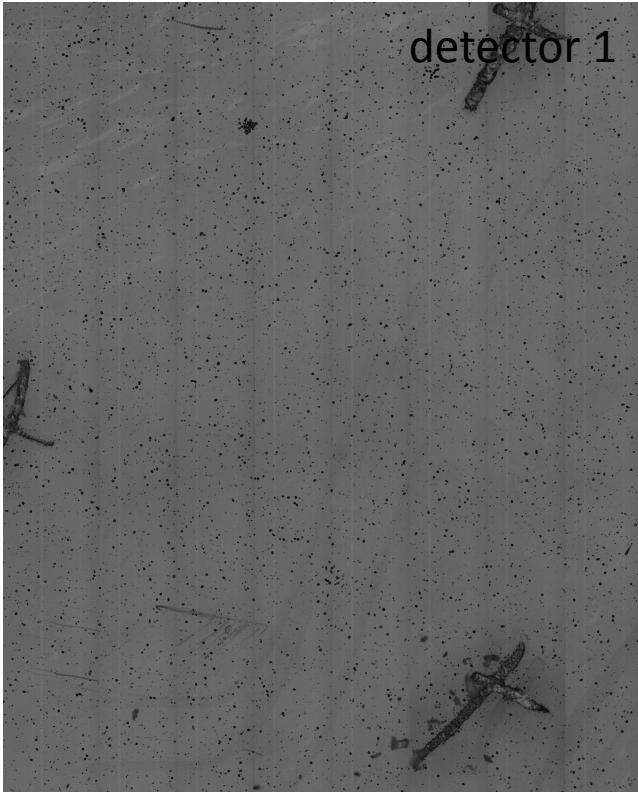
BION-M1

- Aluminum SPD boxes with detectors
- 4 SPD boxes inside the capsule, 2 outside

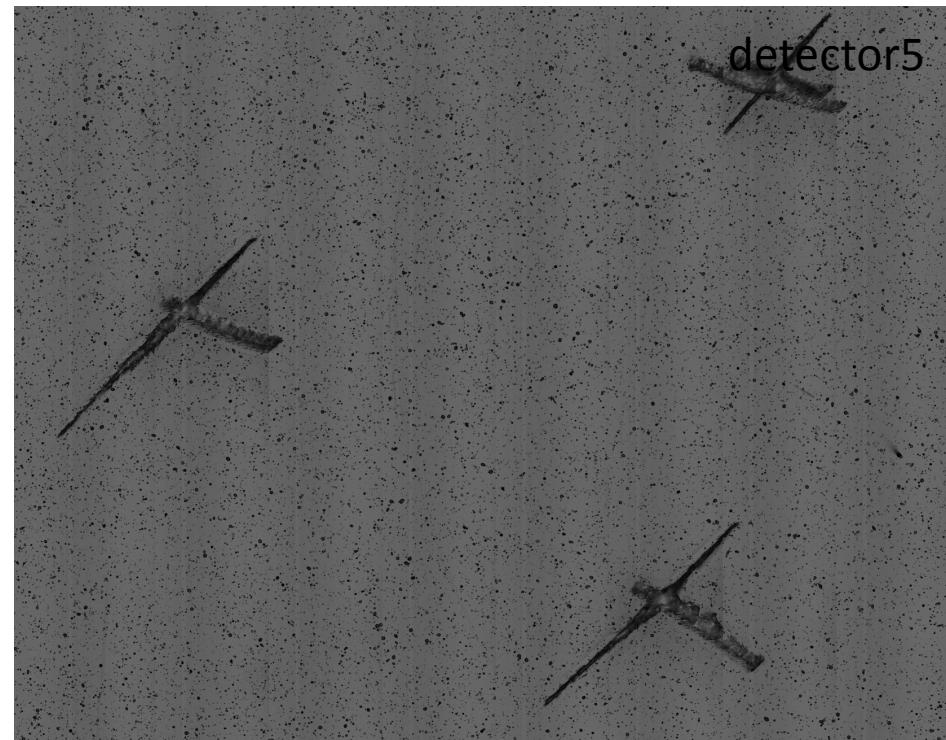


BION-M1

- detector from box 1 (inside) and box 5 (outside)
- 18 + 18 + 18 hours etching



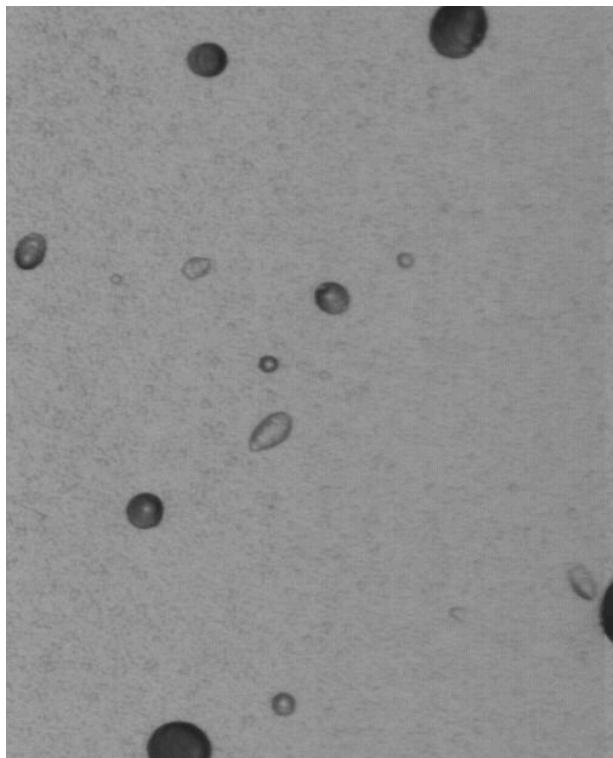
~ 0.4 cm²



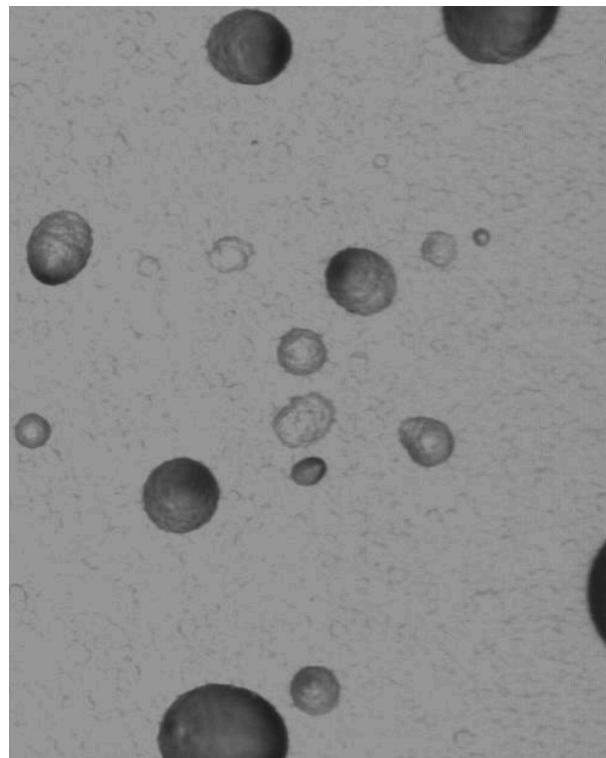
~ 0.25 cm²

BION-M1 – box 1

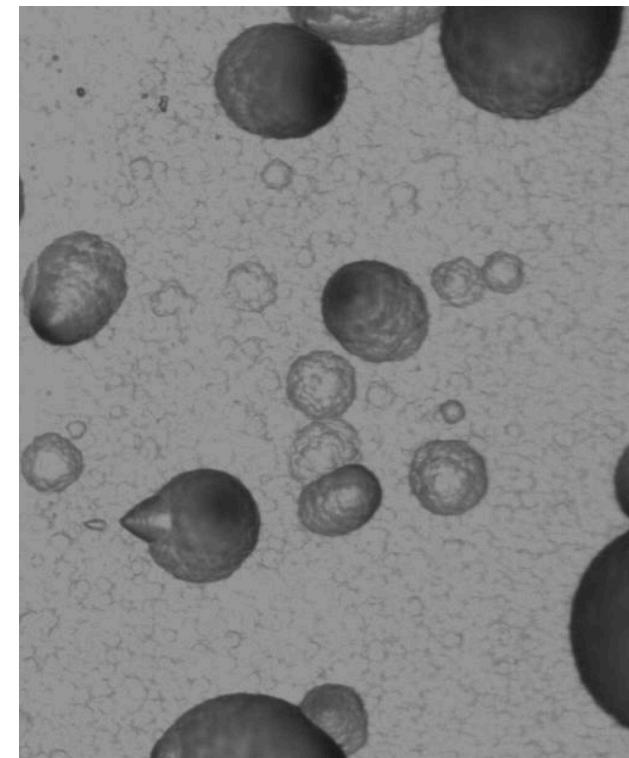
- ~ 0.1 cm², 2611 tracks



18h etching
bulk etch ~ 15 µm



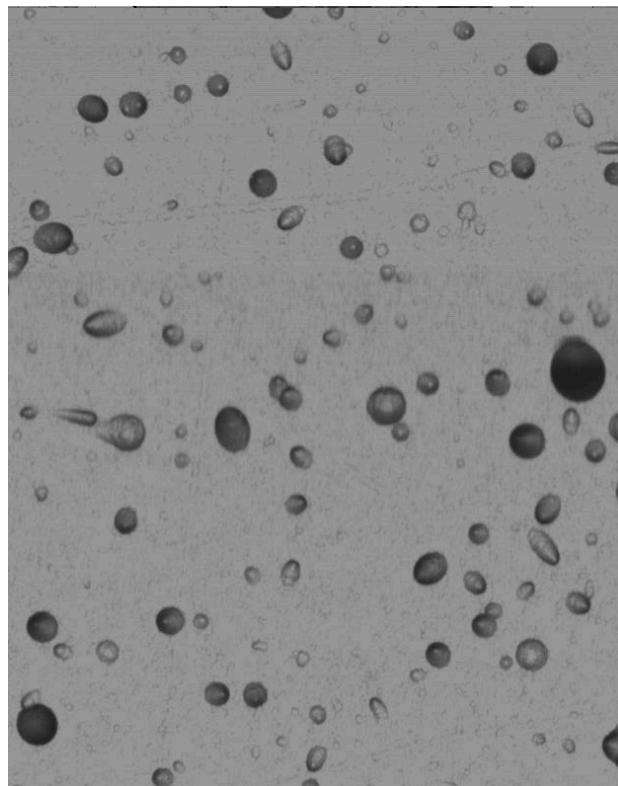
18+18h etching
bulk etch ~ 30 µm



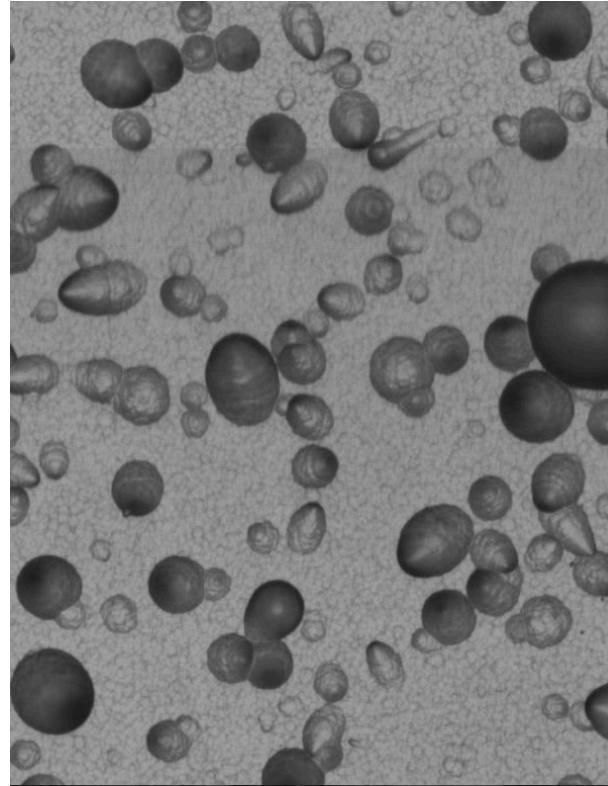
18+18+18h etching
bulk etch ~ 45 µm

BION-M1 – box 5

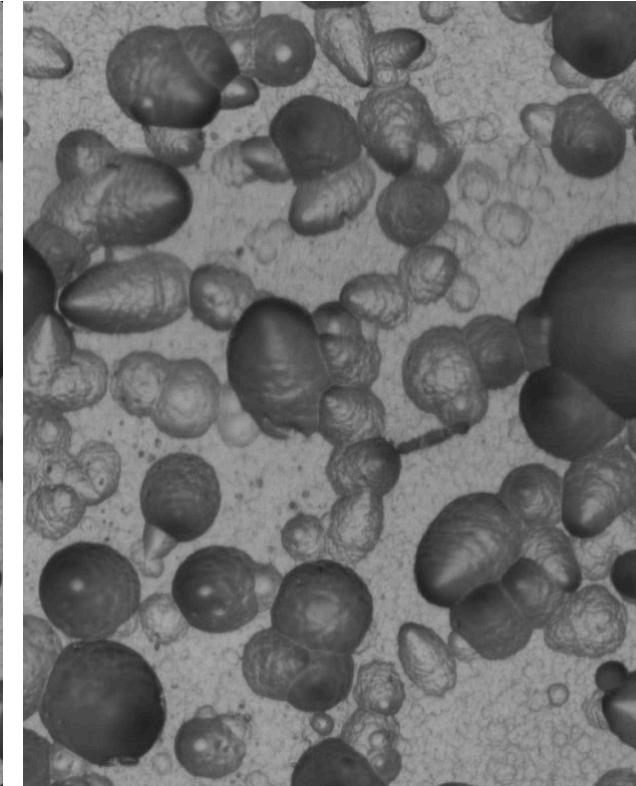
- ~ 0.013 cm², 1785 tracks



18h etching
bulk etch ~ 15 µm



18+18h etching
bulk etch ~ 30 µm

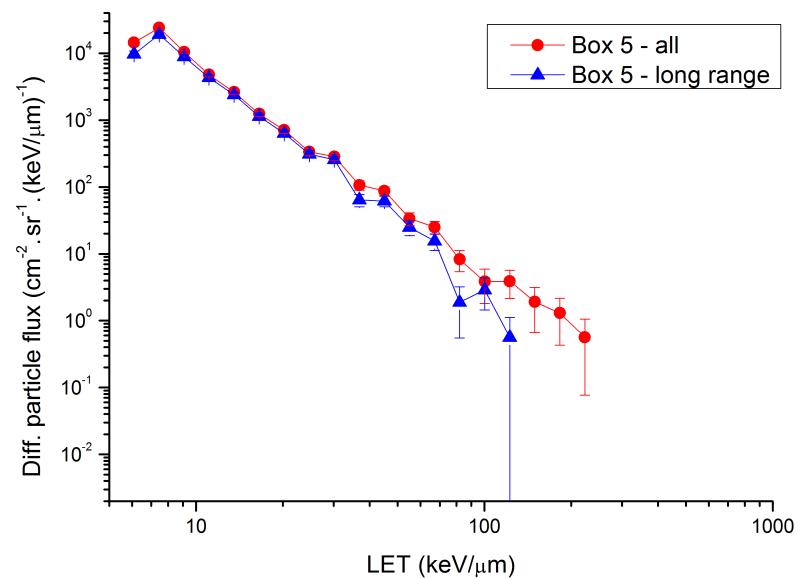
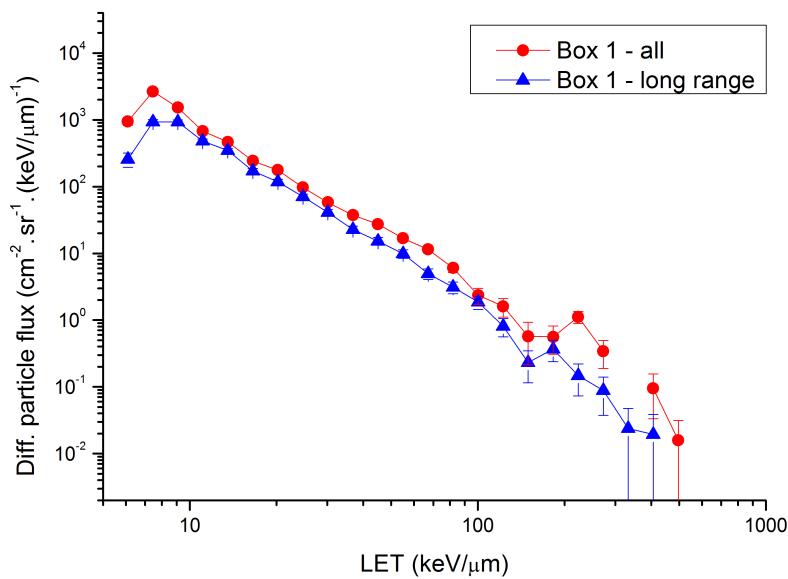


18+18+18h etching
bulk etch ~ 45 µm

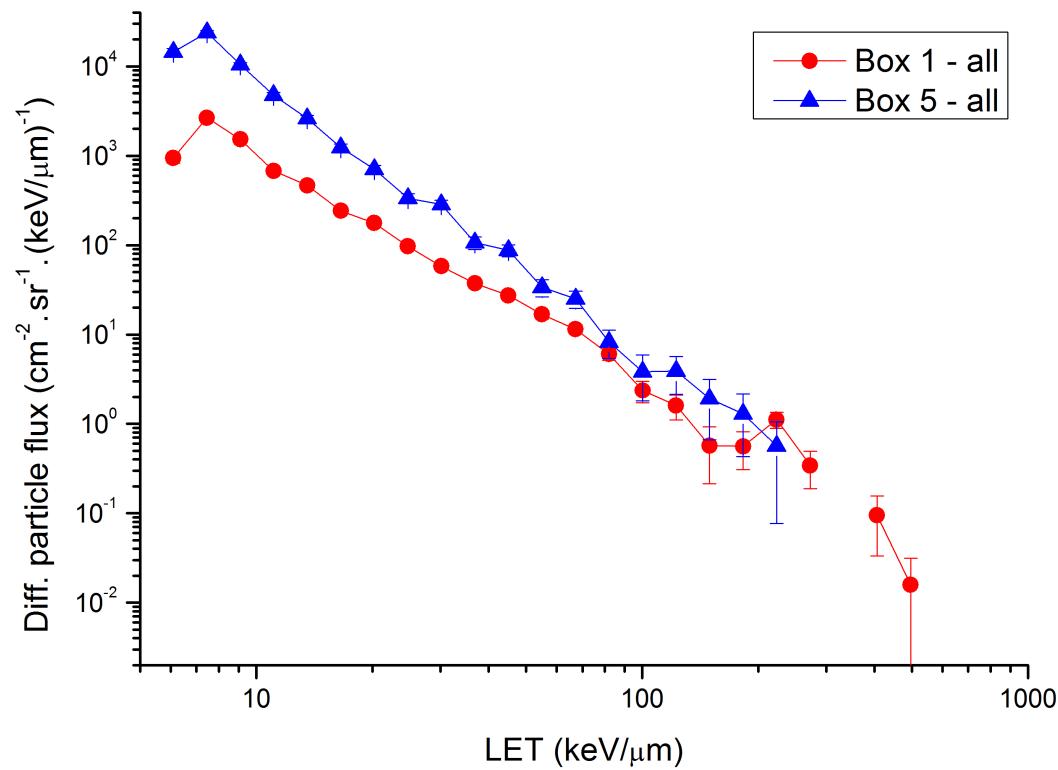
Detected particles

- long-range particles (LET > 7 $\mu\text{m}/\text{keV}$, range > 30 μm)
 - protons with energy from 1.3 to 6 MeV (LET up to 22 keV/ μm)
 - alpha particles with energy from 5 to 130 MeV (LET up to 92 keV/ μm)
 - heavier ions of primary cosmic radiation
- short-range particles
 - primary and secondary low-energy protons (LET up to 85 keV/ μm)
 - low-energy alphas (LET up to 240 keV/ μm)
 - target fragments, such as recoiled nuclei of carbon, oxygen and others

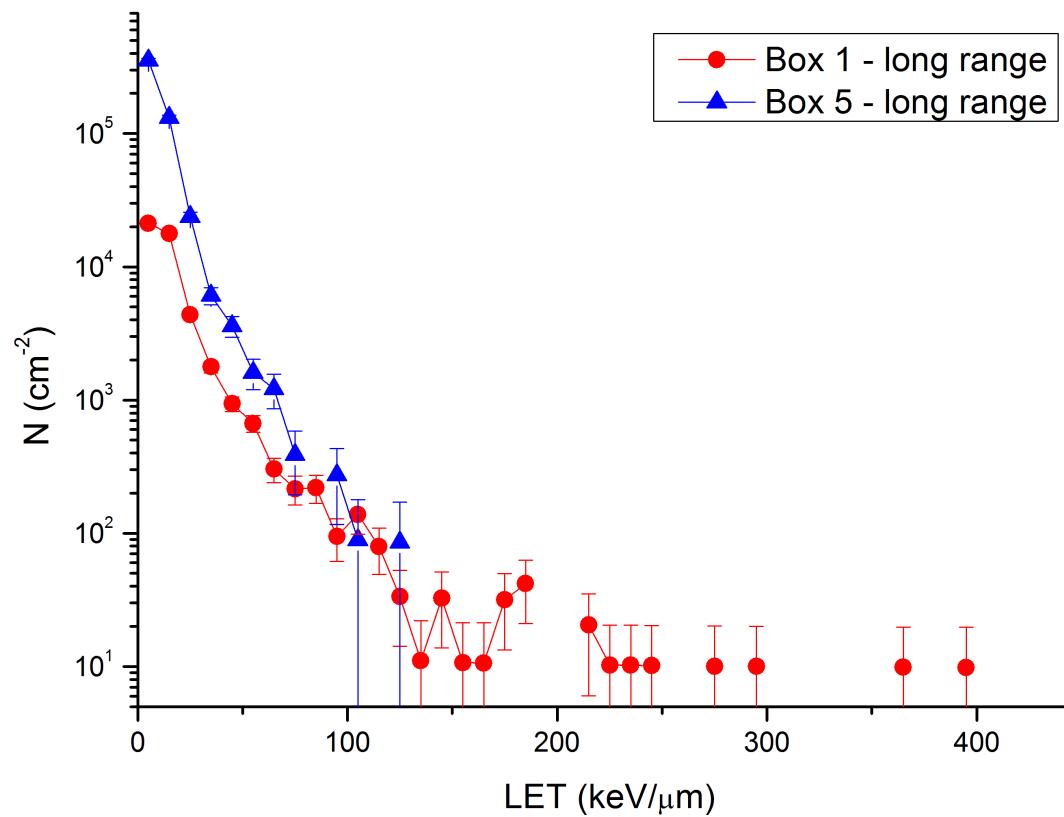
BION-M1 – LET spectra



BION-M1 – LET spectra



BION-M1 – LET spectra



BION-M1 – results

Detector	$N_{\text{all}}/N_{\text{long-range}}$	$N_{\text{long-range}} [\%]$	$D_{\text{all}}/D_{\text{long-range}}$ [mGy]	$D_{\text{long-range}} [\%]$	$H_{\text{all}}/H_{\text{long-range}}$ [mSv]	$H_{\text{long-range}} [\%]$
box 1	2548 / 1468	58	4.6 / 2.6	56	38.5 / 19.7	51
box 5	1722 / 1465	85	22.7 / 18.0	79	93.1 / 58.2	62

Conclusions

- comparison of paired tracks → discrimination of primary high-energy nuclei of cosmic radiation from the secondary short-range particles
- high-energy ions with long range
 - about 85% of all detected particles outside and about 60% inside the satellite
 - contribution to the absorbed dose about 80% outside and 55% inside the satellite
 - contribution to the dose equivalent about 60% outside and 50 inside the satellite

Remarks

- contribution of short-range particles can be much higher, depending on the etching conditions
- identification of ions of primary cosmic radiation

Acknowledgement

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