# Correct identification of energetic alpha and proton tracks in experiments on CR-39 charged particle detection during hydrogen desorption from Pd/PdO:Hx heterostructure

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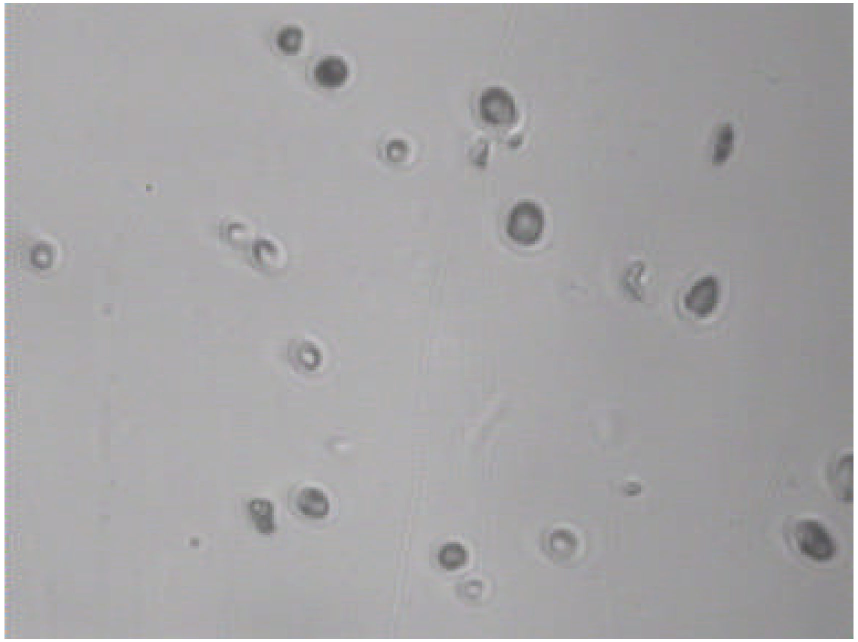
# Introduction

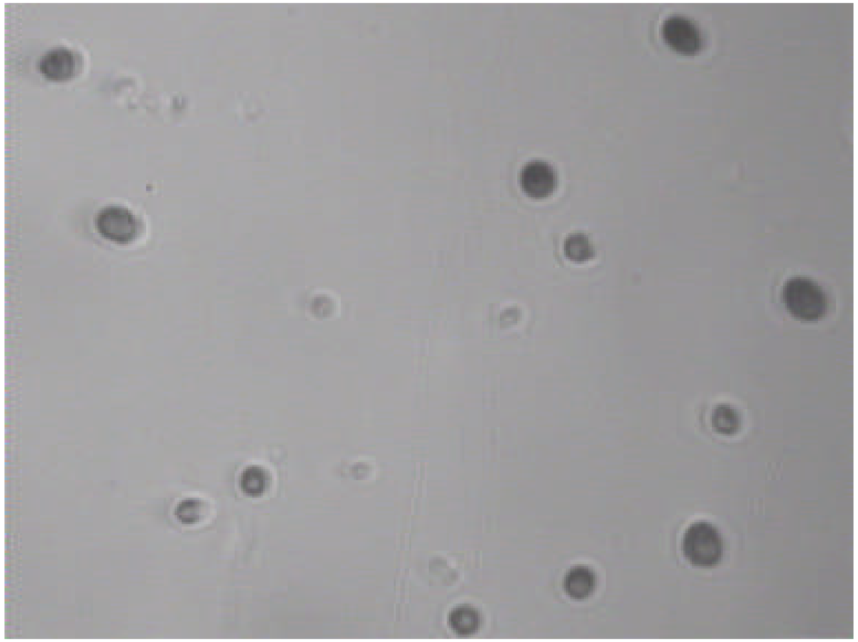
Earlier experiments have showed emissions of energetic charged particles ($\alpha$-particles and protons) during exothermic H desorption from the Pd/PdO:Hx heterostructures. The occurrence of these emissions was confirmed by independent experiments using both Si-surface barrier and CR-39 plastic track detectors. Earlier we already showed that purified CR-39 plastic track detectors can be considered as an adequate scientific instrument, which suitable for detection of individual uniformly distributed charged particles and also for the groups of these particles being emitted from the active spots ("hot zones") attributed to the maximum internal strain area at the surface of $PdD_x$ and $TiD_x$ samples. The analysis of CR-39 data showed that in some cases energetic charged particle tracks ($\alpha$-particles and protons) concentrated inside the small spots of detector. The typical "hot zone" with ~200 tracks within the area with the size of 0.2x0.5 $mm^2$ were found to be appeared during the hydrogen desorption experiments with Pd/PdO:Hx samples.

- In present work we demonstrate the advance of track detection technique allowing to perform an unambiguous identification of CR-39 tracks in order to obtain full information about type and energy of detected particles as well as to distinguish them from usual background events and surface defects.

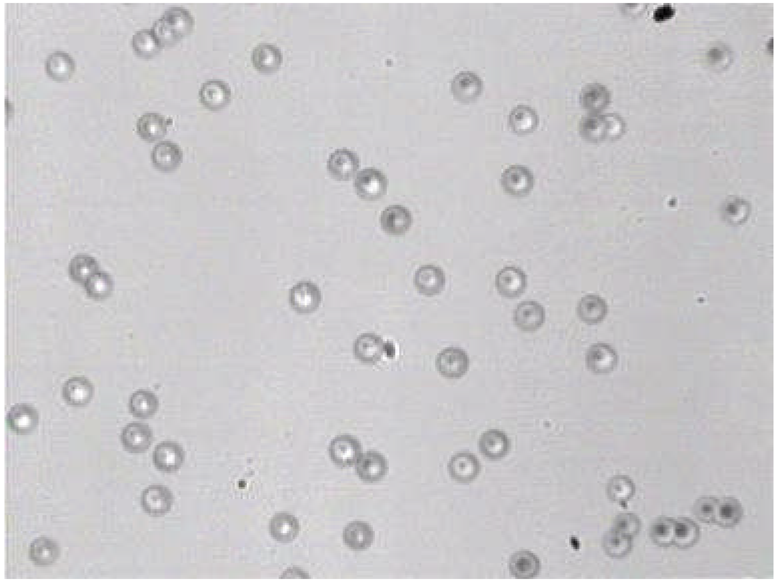
# PAVICOM – completely automated device for track detector processing

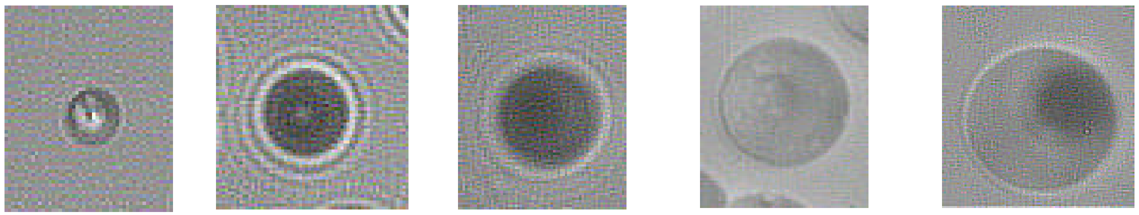
**CR-39 measurement after electrolysis of Pd/PdO:$H_x$ (50 $\mu$m)**
**Shielding of CR-39 – 11 $\mu$m of Al**
**Photomicrographs of "hot zone" (250x500 $\mu m^2$ ) with tracks of $\alpha$-particles and protons**
**Image size – 120 x 90 $\mu$m**





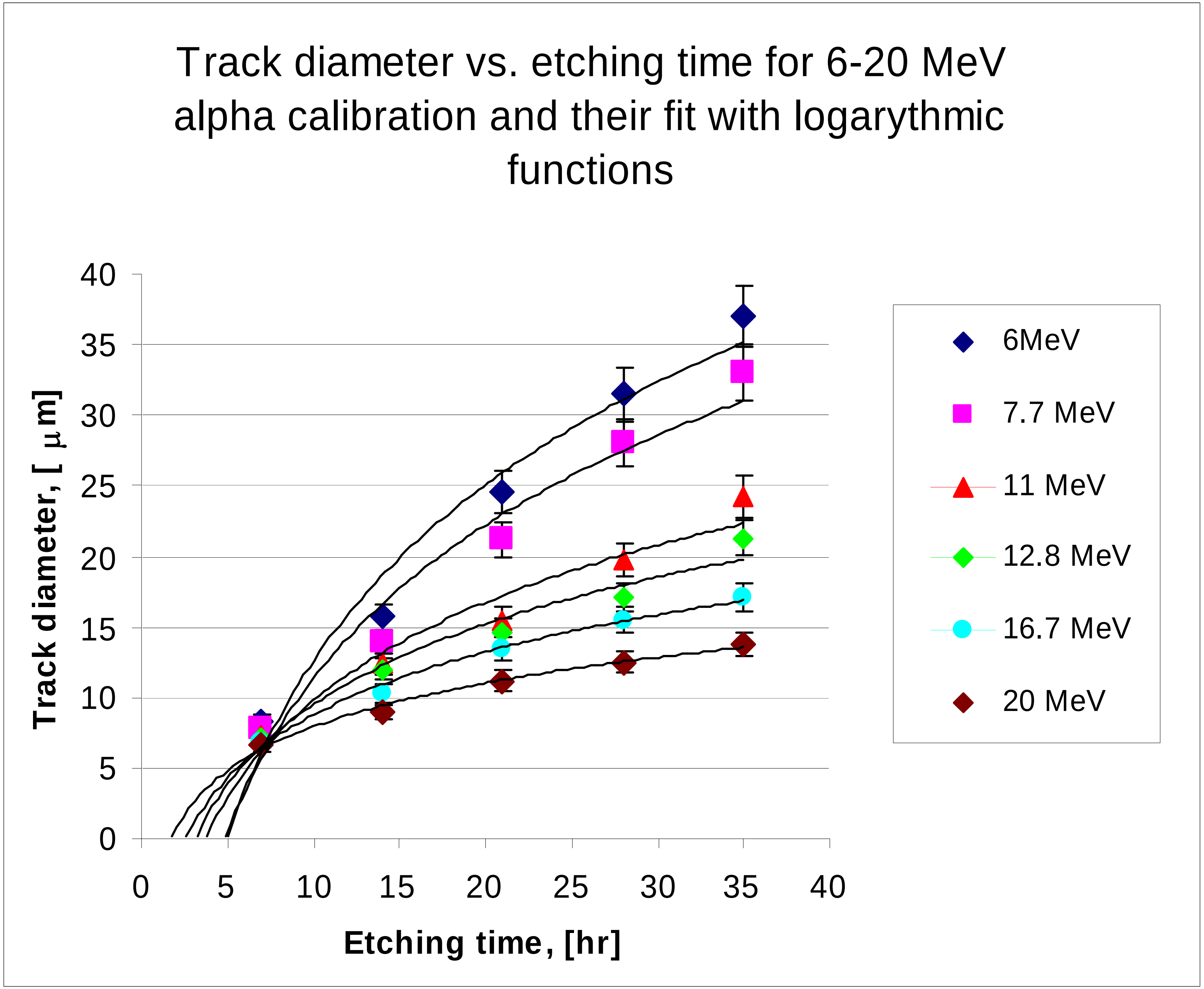
# Tracks from $\alpha$-particle cyclotron beam ($E_\alpha$ = 11 MeV) normally incident on CR-39 detector. Image size – 120 x 90 $\mu$m





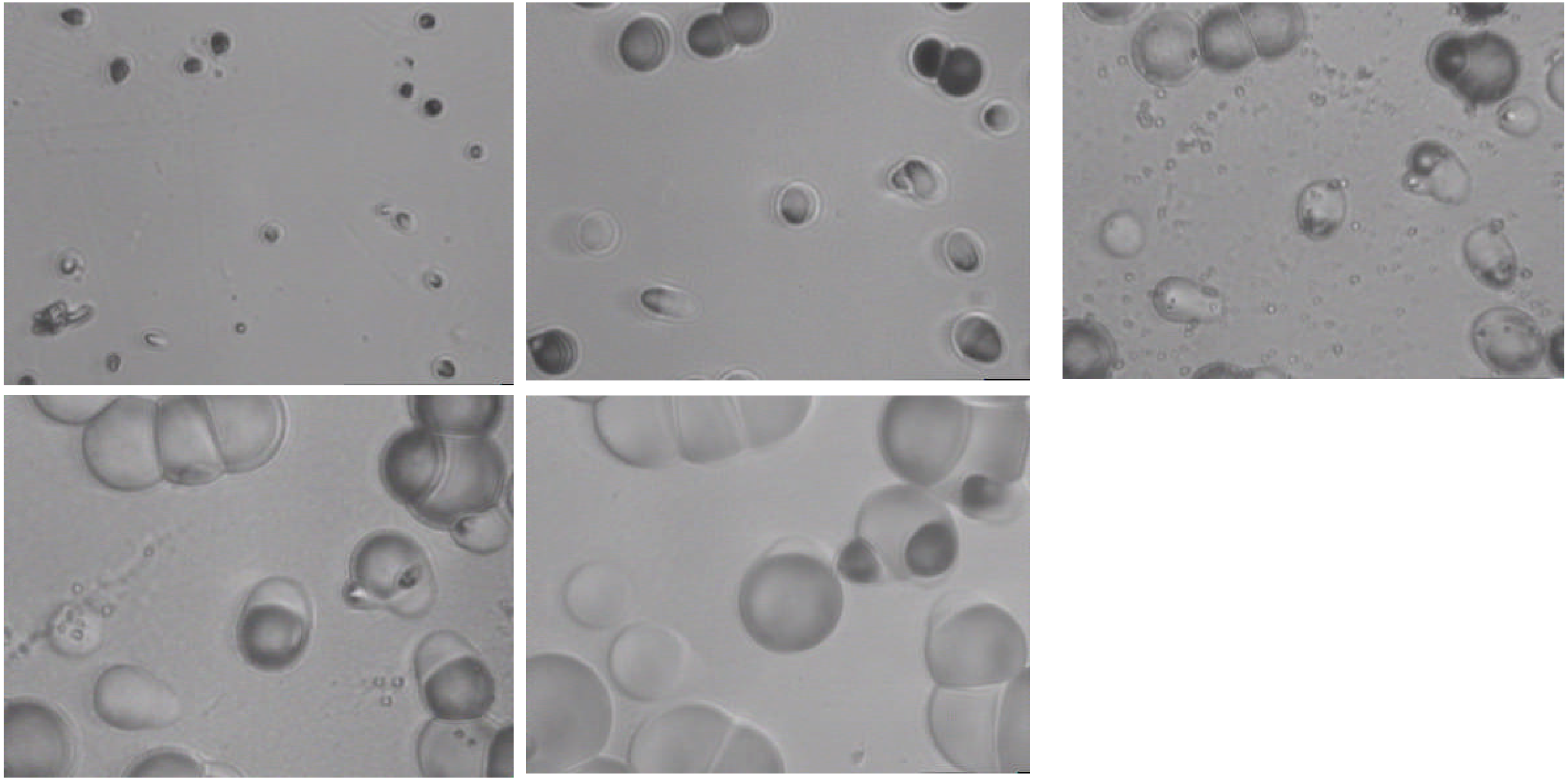
11 MeV alpha track etch dynamic

- 1) t = 7.0 hr  2) t=14.0 hr  3) t=21 hr  4) t=28 hr  5) t = 35 hr.

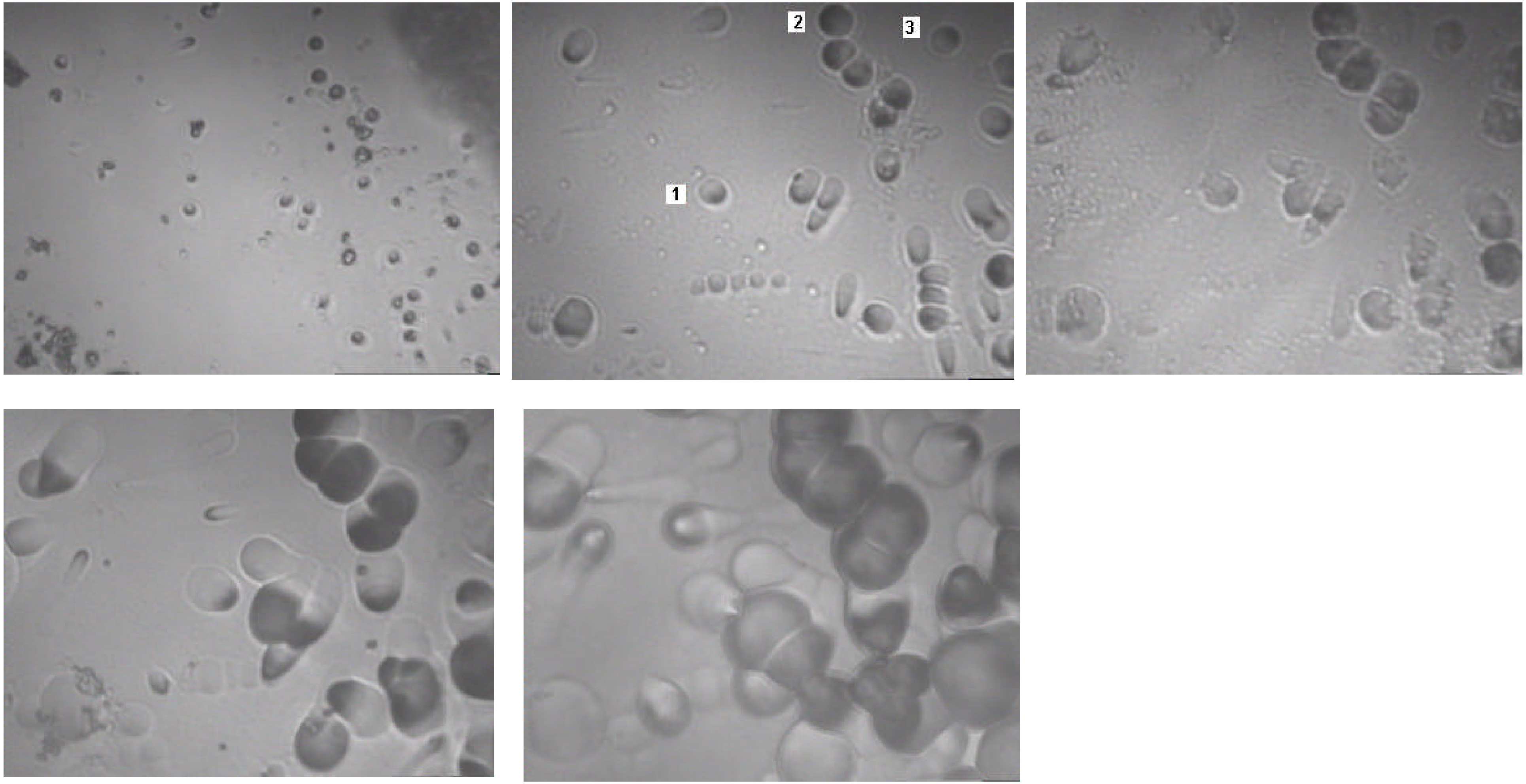


Track diameter vs. etching time for 6-20 MeV alpha calibration and their fit with logarythmic functions
Track diameter, [ μm]
Etching time, [hr]
0
5
10
15
20
25
30
35
40
6MeV
7.7 MeV
11 MeV
12.8 MeV
16.7 MeV
20 MeV

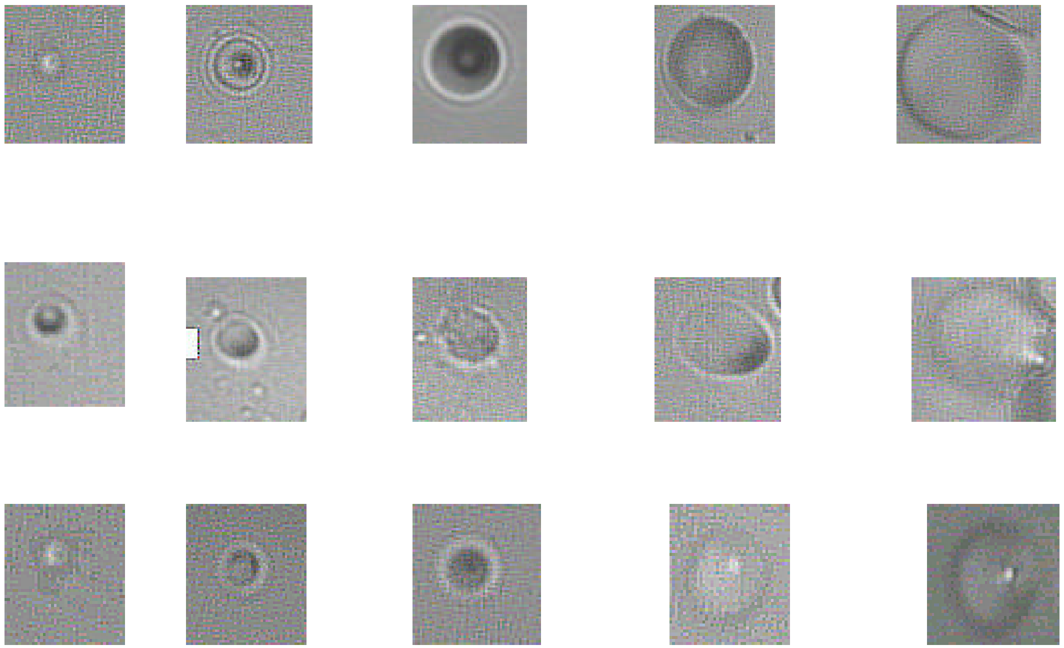
Hot zone: the spot with coordinates: [-433,-2285],
track etch dynamic at etching time – 7, 14, 21, 28 and 35 h.



Hot zone: the spot with coordinates: [-71, -1972] track etch dynamic at etching time – 7, 14, 21, 28 and 35 h.



# Examples of comparison proton calibration track etch dynamic with that of proton candidate

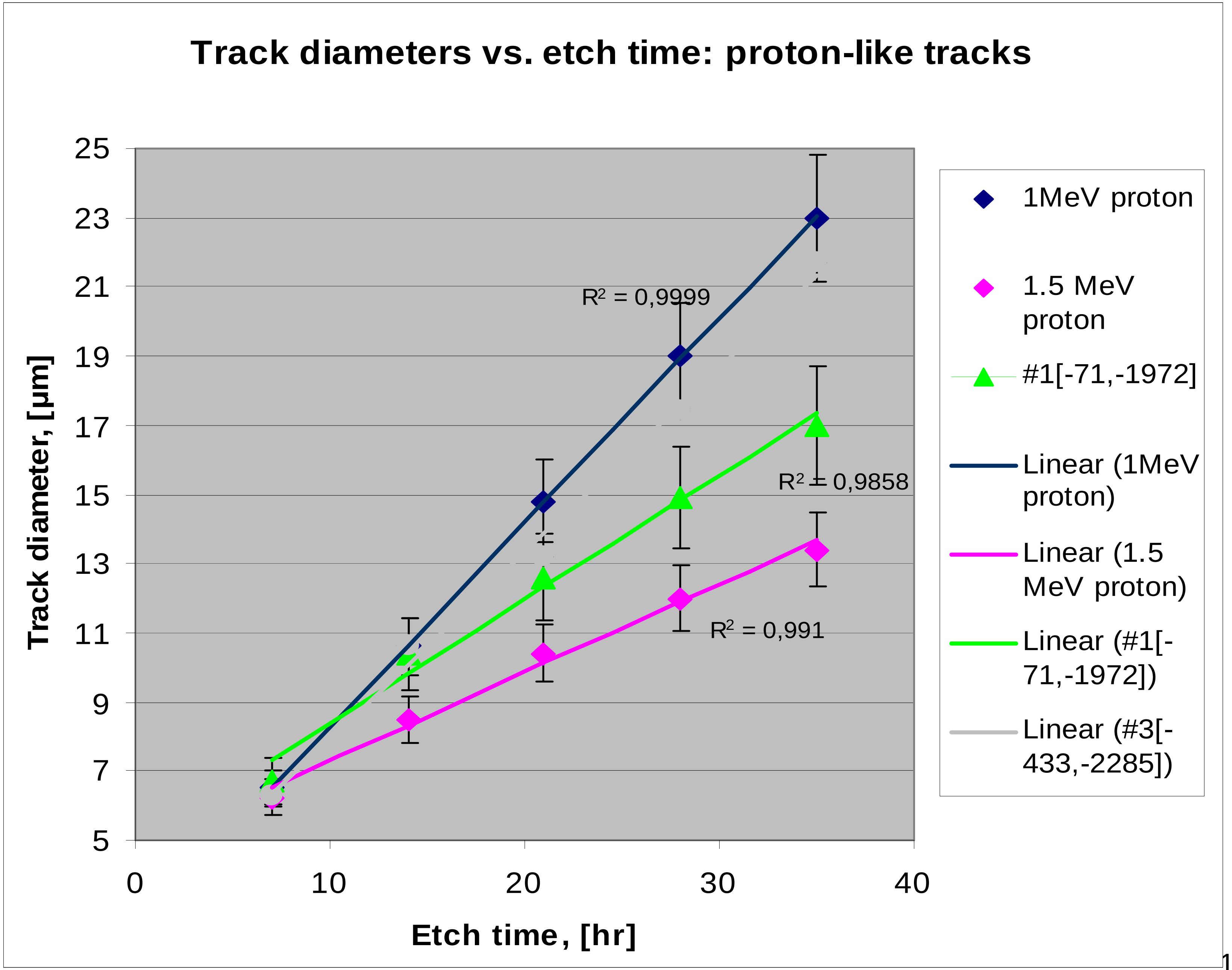


1 MeV Proton calibration

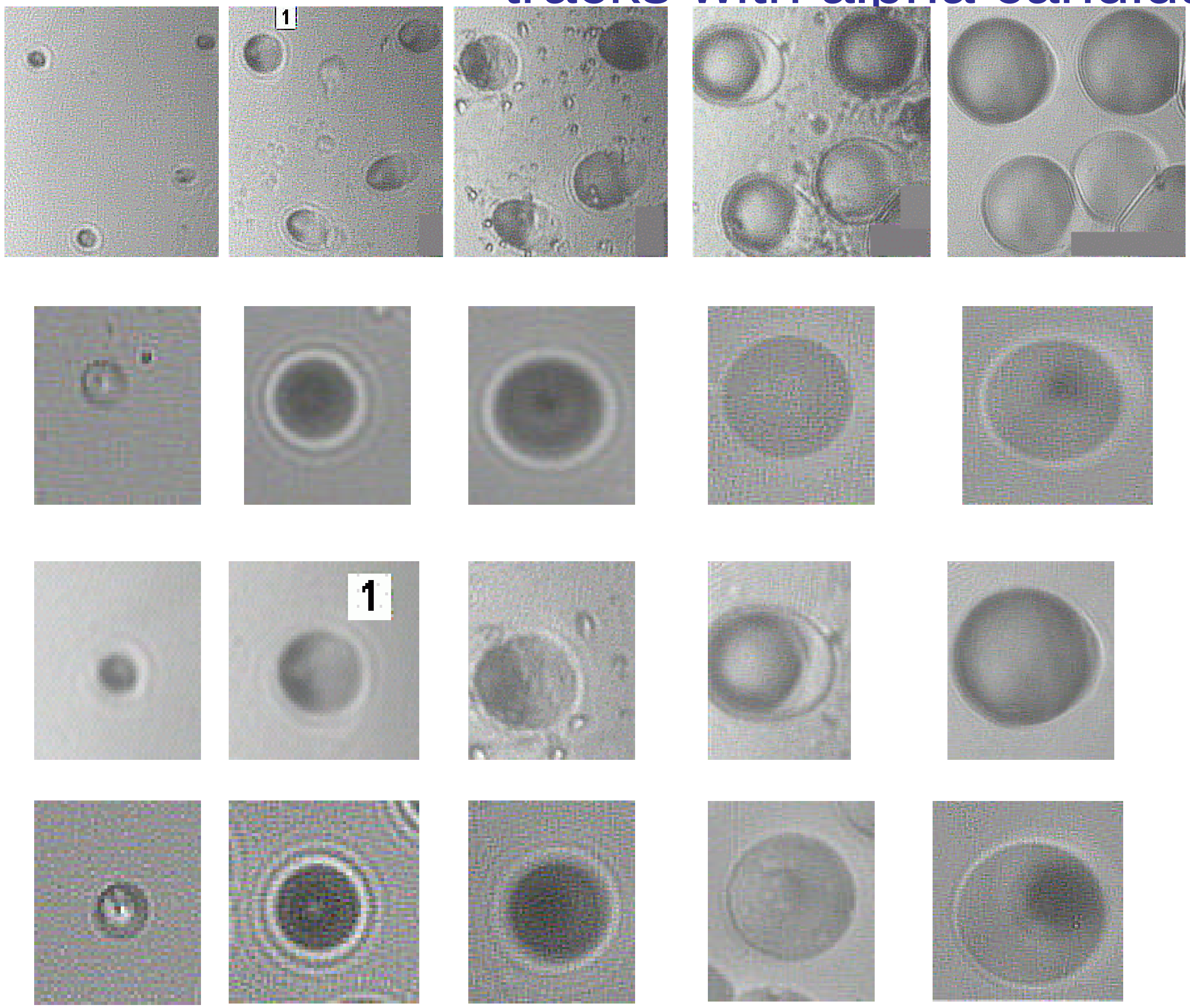
[-71;-1972], track#1 proton

1.5 MeV Proton calibration

- 1) t = 7.0 hr  2) t=14.0 hr  3) t=21 hr  4) t=28 hr  5) t = 35 hr.


Track diameters vs. etch time: proton-like tracks
Track diameter, [µm]
Etch time, [hr]
25
23
21
19
17
15
13
11
9
7
5
0
10
20
30
40
R² = 0,9999
R² = 0,9858
R² = 0,991
1MeV proton
1.5 MeV proton
#1[-71,-1972]
Linear (1MeV proton)
Linear (1.5 MeV proton)
Linear (#1[-71,-1972])
Linear (#3[-433,-2285])

# Example of comparison 11 and 12.8 MeV alpha calibration tracks with alpha candidate



the spot [-116,-1621] –4 track group

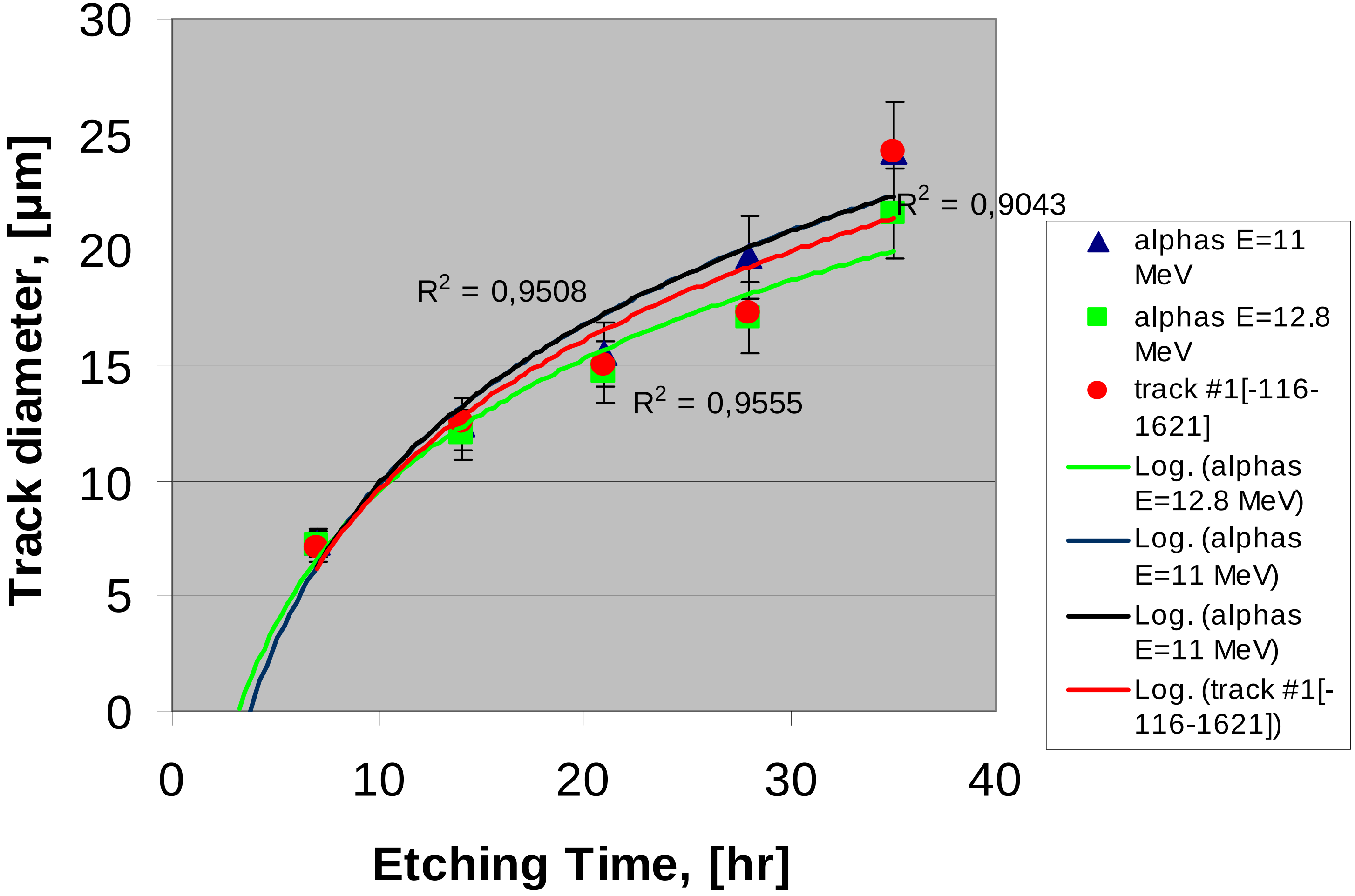
12.8 MeV alphas

track #1 [-116,-1621]

11 MeV alphas

1) t = 7.0 hr  2) t=14.0 hr  3) t=21 hr  4) t=28 hr  5) t = 35 hr.

# Comparison of track #1 [-116, -1621] etching dynamics with that for 11 and 12.8 MeV alphas



# The dependence of track etch rate $V_t$ vs. track diameter D and removable depth h for normal incidence

- In simple model of track etch dynamic

$$D = 2h\,[(V - 1)/(V + 1)]^{1/2}$$

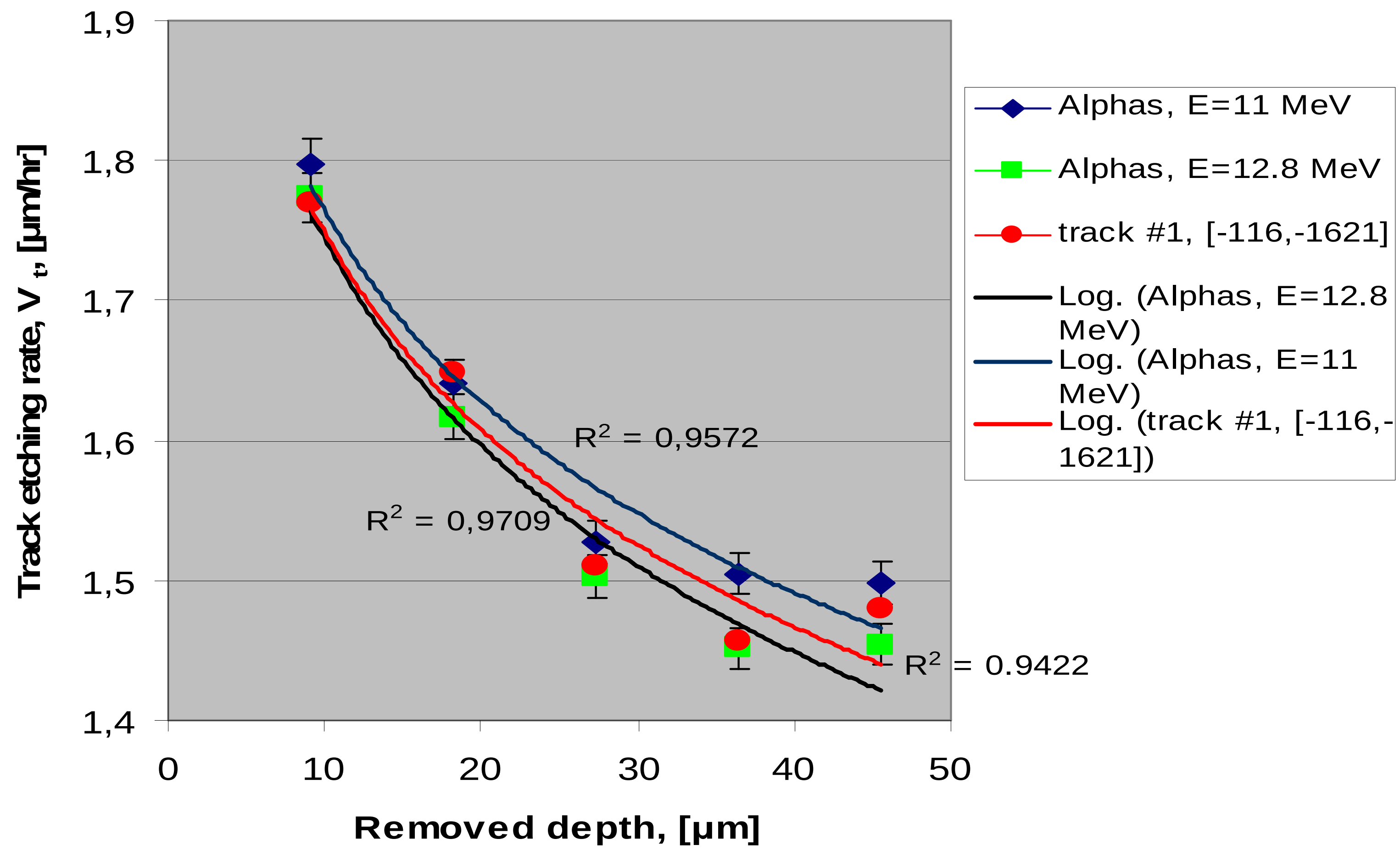
$V = V_t / V_b$ – track etch ratio

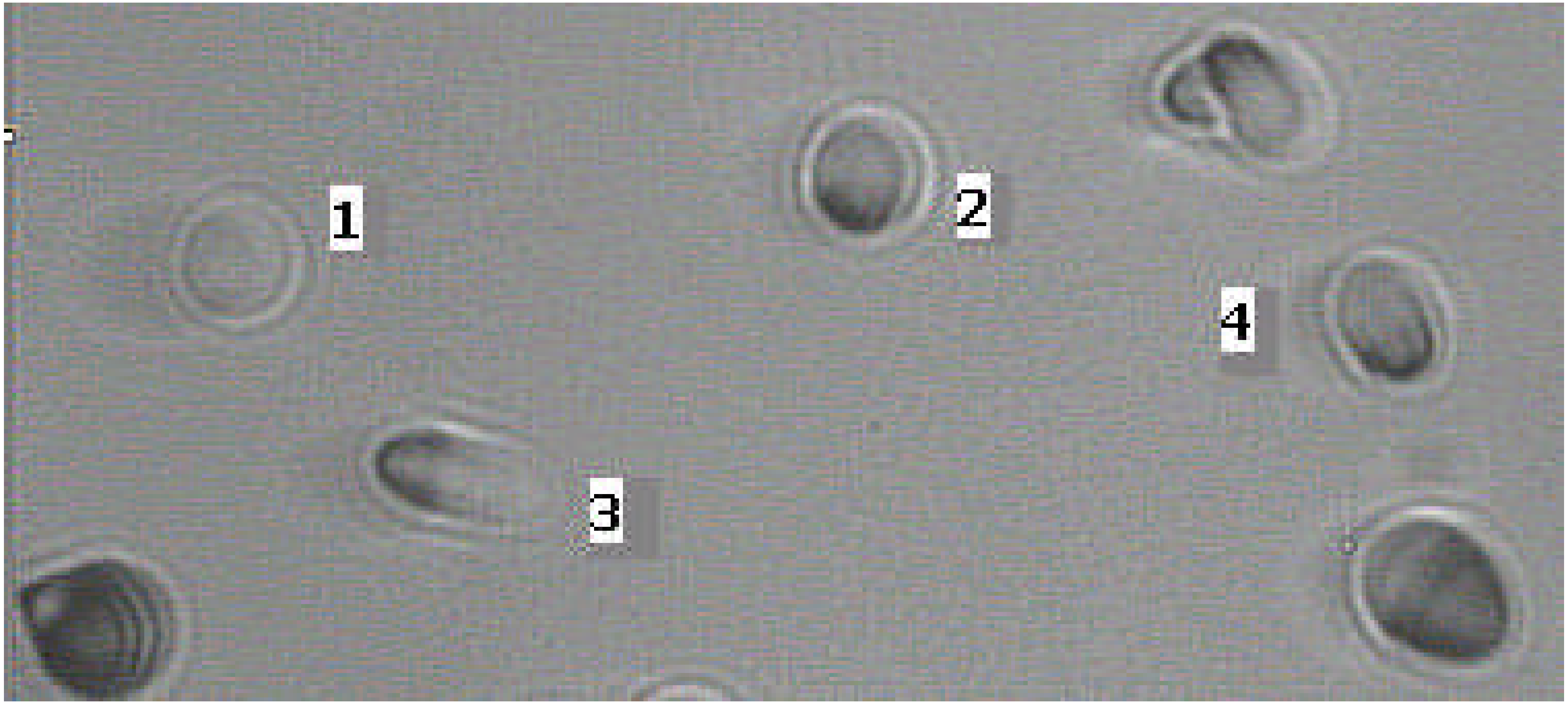
$V_b = 1.3$ μm/h – bulk etch rate for etching in 6N NaOH at 70˚C

$h = V_b\,t$ – removed depth

$$Vt / Vb = [(2h)^2 - D^2] / [(2h)^2 + D^2]$$

## Rate of track etching $V_t$ vs. removed depth of CR-39 for 11 and 12.8 MeV alphas and track #1[-116,-1621] at $V_b$ = 1.3 μm/hr

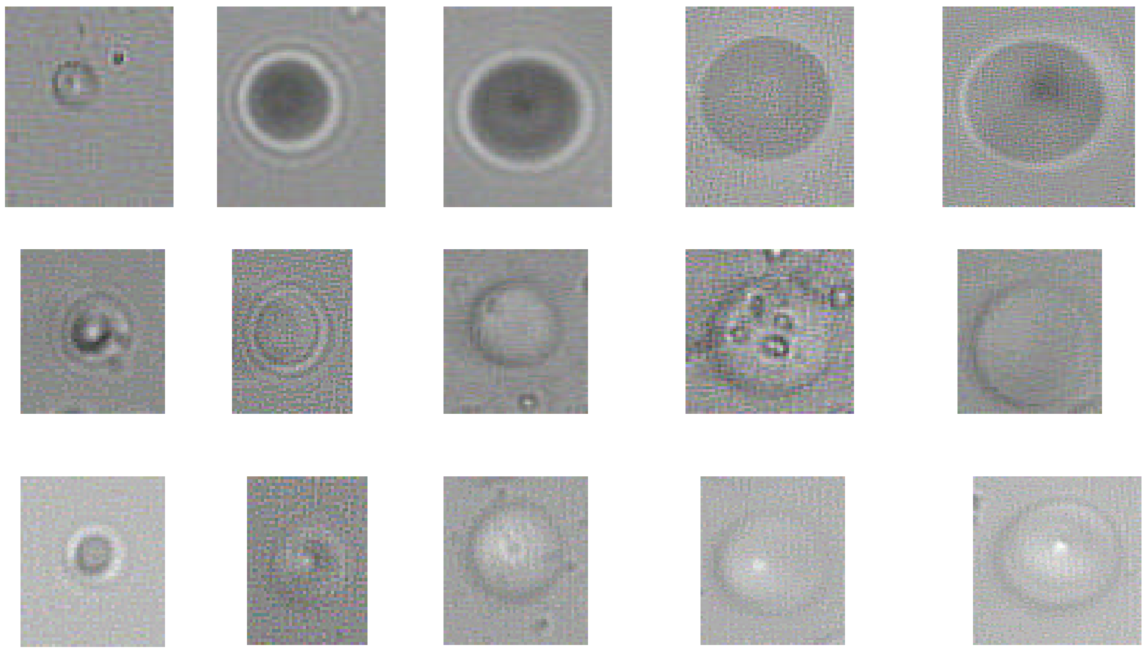





Hot zone: the spot with coordinates: [-433,-2285]

# Example of comparison 12.8 and 16.7 MeV track etch dynamic with that of alpha candidate

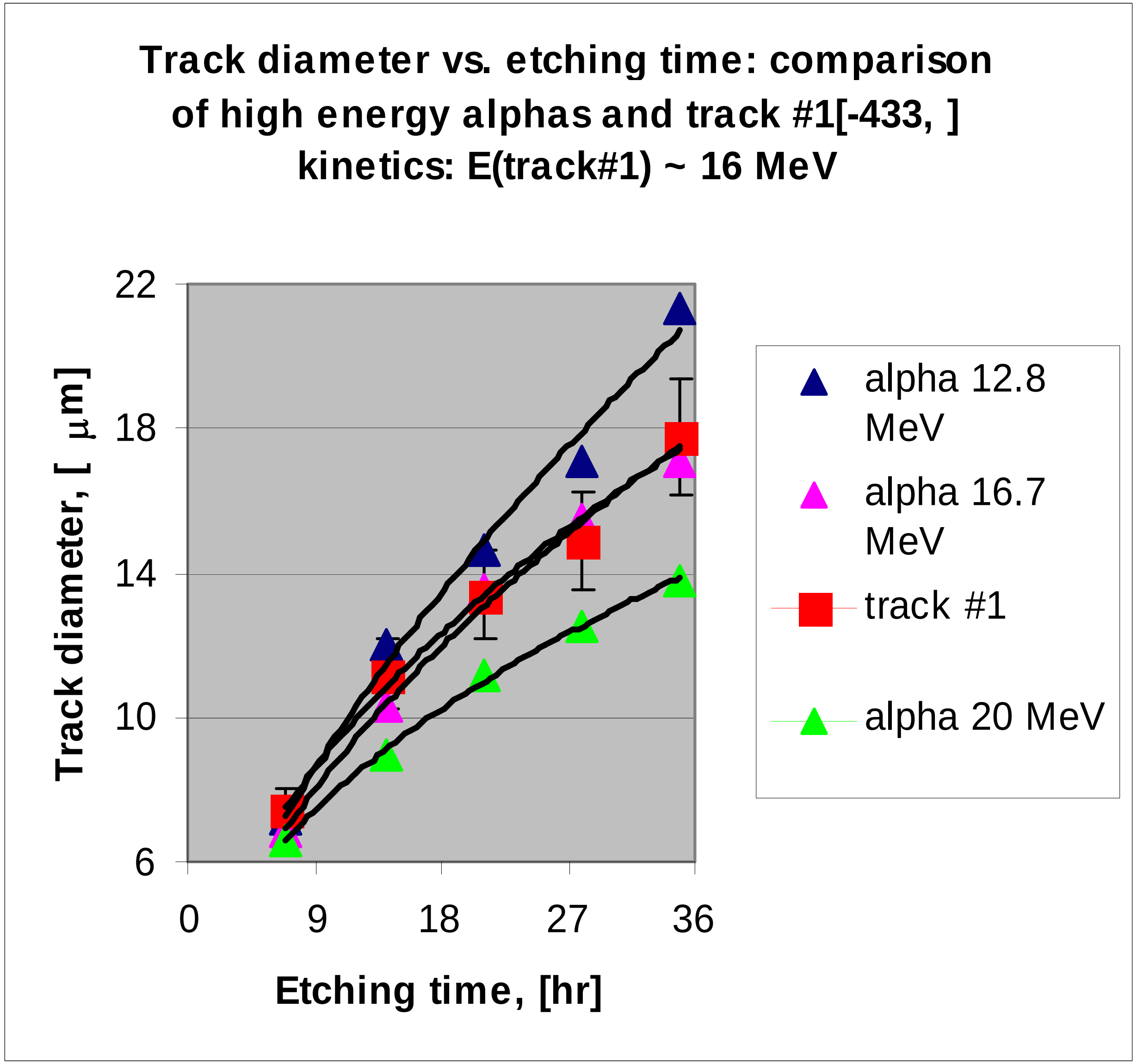
•1) t = 7.0 hr  2) t=14.0 hr  3) t=21 hr  4) t=28 hr  5) t = 35 hr.



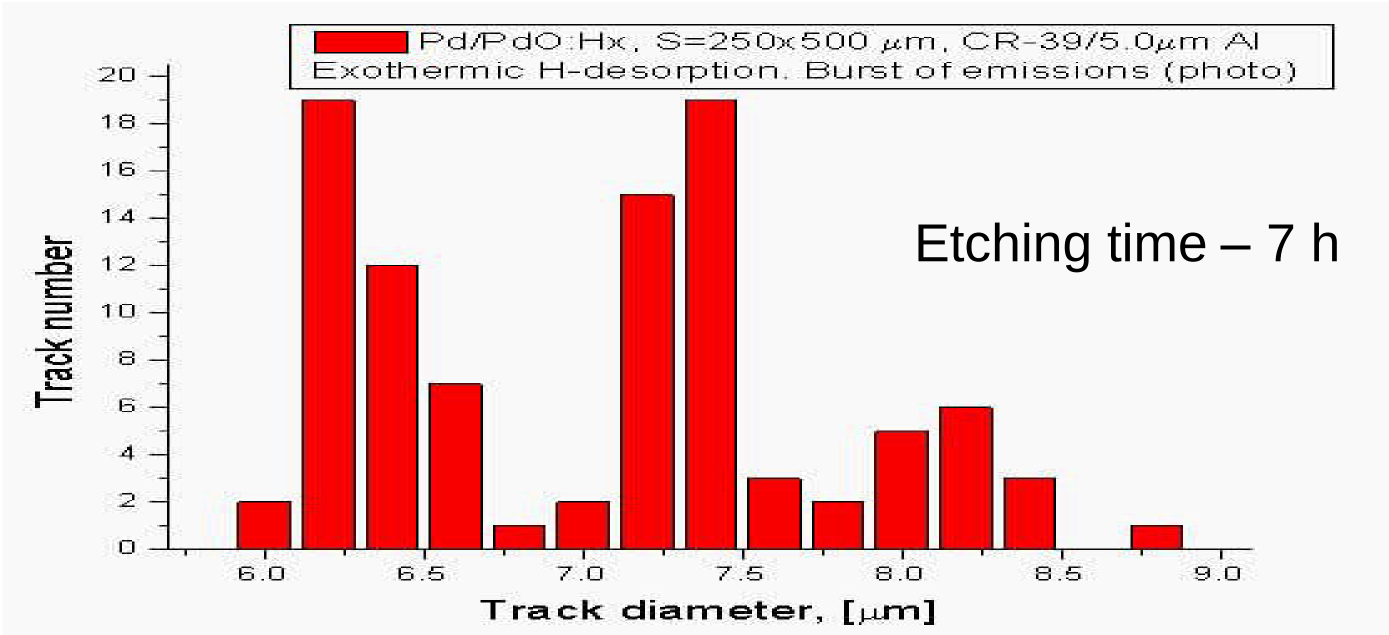
12.8 MeV alphas

[-433;-2285], track #1

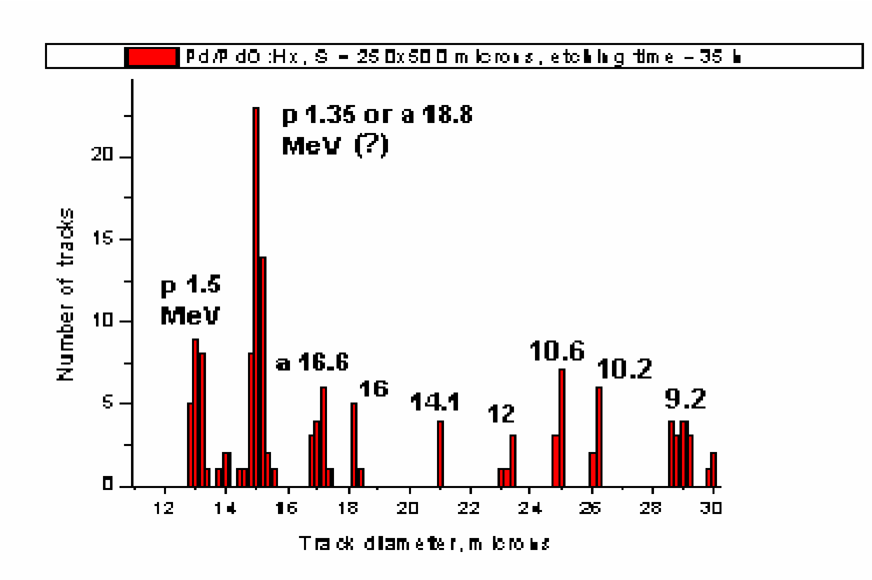
16.7 MeV alphas


Track diameter vs. etching time: comparison of high energy alphas and track #1[-433, ] kinetics: E(track#1) ~ 16 MeV
Track diameter, [ µm]
22
18
14
10
6
0
9
18
27
36
Etching time, [hr]
alpha 12.8 MeV
alpha 16.7 MeV
track #1
alpha 20 MeV

## Distributions of track diameters in “hot zone” (250 x 500 $\mu m^2$)




Etching time – 7 h




Etching time – 35 h

Take into account the shielding 11 μm of Al, we can to estimate the energies of primary particles:

- Alpha particles emitted with primary energies

  10.4 ± 0.3; 11.6 ± 0.3; 13.0 ± 0.2;

  15.0 ± 0.2; 16.7 ± 0.2; 17.4 ± 0.3 MeV

- Protons emitted with primary energy

  ~ 1.7 – 1.9 MeV

# Conclusion

- We unambiguously identified tracks of as minimum 2 groups of alpha particles with energies 10 – 13 and 15 – 17.5 MeV. The emission of such alphas was previously measured by CR-39 detectors with different shielding.
- We confirmed the emission of protons with energies ~1.7 – 1.9 MeV during of exothermic hydrogen desorption from Pd/PdO:Hx samples.
- The comparison of track etch dynamic of calibration a's and protons including functions D = f(t) and $V_t$ = f(h) with that of individual tracks, unambiguously confirms the effect of energetic charged particle emission from surface of metals with high affinity to hydrogen.
- Method of track depth measurement to improve the energy resolution and separation different types of particles is on the way.