Energetic Charged Particle Emission from the Hydrogen Loaded Pd and Ti Cathodes and its Enhancement by a He-4 Implantation

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Introduction I

- Detection of energetic nuclear products easily distinguished from the Background/cosmic emissions would be a strong evidence for LENR existence in non-equilibrium metal deuterides.
- Charged particles from DD-reaction (3.0 MeV p and 1.0 MeV t) show very low intensity and appear at such energy range where the background counts are typically non-negligible.

Introduction II

- First detection of particles E > 8.0 MeV in Au/Pd/PdO:D(H)x during exothermic D/H-desorption: A.G. Lipson et al., Bull. Lebedev Phys. Inst., No.10, 22(2001).
- Spectra of alpha particles in electrolysis and GD are similar to that obtained from powerful laser irradiation of Ti hydrides/deuteride target.

Objectives

- Search of energetic charged particles (ECP) signatures using SSB and CR-39 track detectors techniques in D(H)-loaded metals with a large hydrogen solubility.
- Confirmation of LENR occurrence by comparison of ECP emissions from Pd/Ti with the detector's background response and runs with other metals .
- Study of He-4 implantation effect on the ECP emission parameters during and after electrolysis of Pd cathode. Search for enhancement of ECP yield ?

Detection technique I

- Si-surface barrier detectors (ORTEC) of various efficiency calibrated with ^{241}Am alpha-source operated in vacuum 10^{-3}-10^{-6} torr: SSB(1): S=100 mm^2, SSB(2): S=900 mm^2 (d=10-20 mm).
- dE-E SSB detector pair (dE->20 μm, E->100 μm, time gate $\Delta\tau$ = 20 ns) in air at ambient condition: 2- dimensional spectra for particle identification

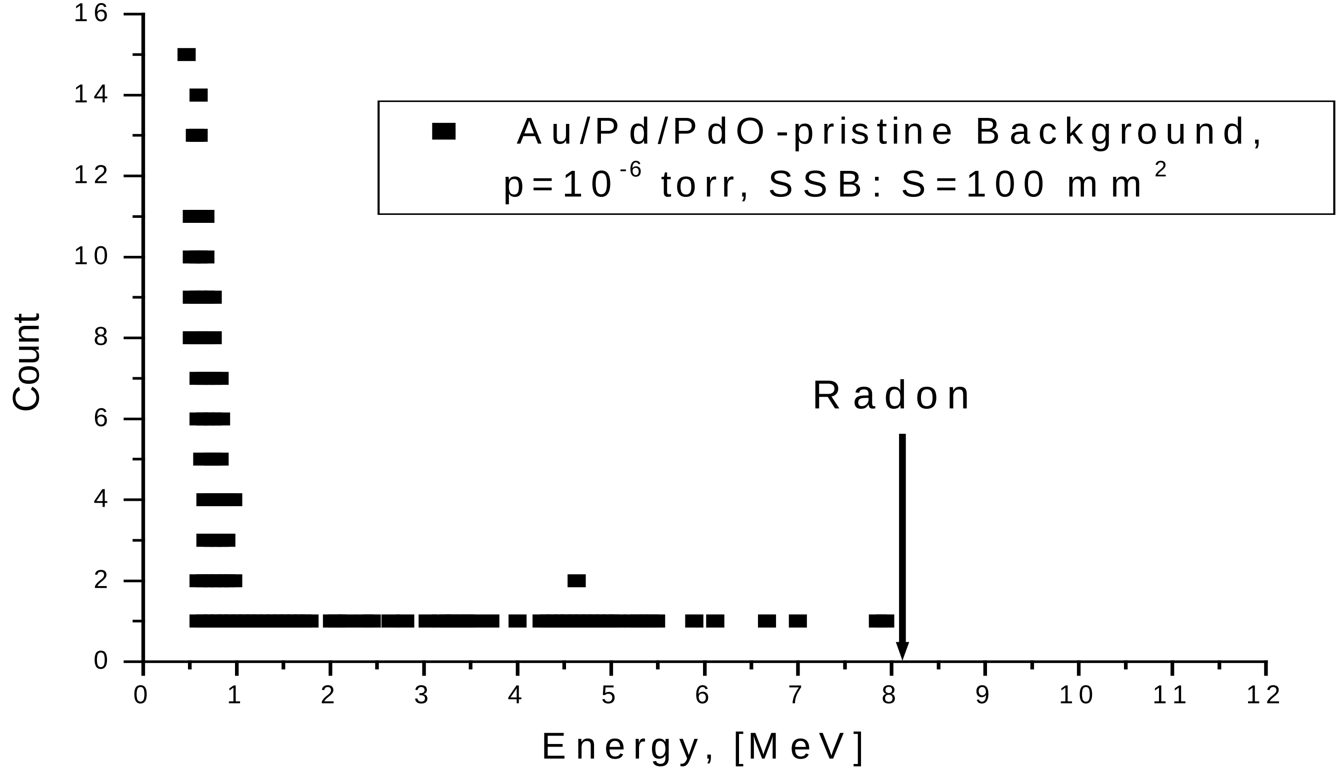
Detection technique II

- CR-39 detectors (purified: < 20 track/cm^2) Landauer (USA), S=2 x 1 cm^2 attached to cathode in electrolysis;
- Various metal foils used as a shielding (11-66 μm Al, 25-50 μm Cu) allow identify charged particle accordingly to stopping range.
- Accelerator p/α calibration of detectors
- CR-39 Etching: 6MNaOH, t= 70 °C, τ=7 hr: Foreground and Background detectors were etched simultaneously.

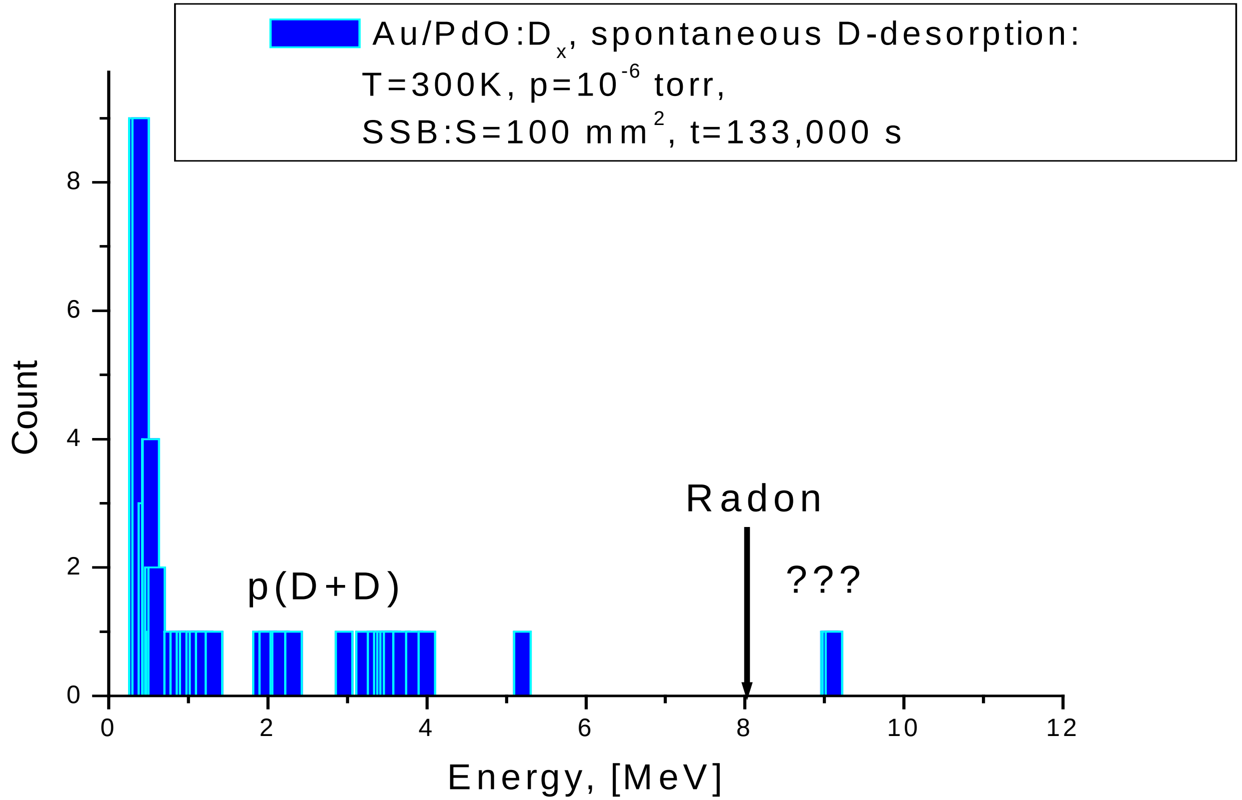
Samples

- Electrochemical loading of Ti, Pd/PdO and Au/Pd/PdO:D_x (1M-Li_2SO_4/H_2O; 1M NaOD/D_2O; j=20 mA/cm^2) heterostructure (40-60 μm thick): *in-situ* during electrolysis and/or D/H-desorption @ T=300 K (SSB measurements only after electrolysis + CR-39).
- Alumina/Pd(600nm), Glass/Pd(250 nm) thin film cathodes electrolysis: CR-39 *in-situ* measurements (1MLi_2SO_4/H_2O, j=10 mA/cm^2).
- Ti, and Pd/PdO foils implantation with He-4 ions using He-gun: total fluence $\Phi = 2x10^{16}$ ^{4}He/cm^2, E_{He} = 20 keV (R_{He} ~ 20-30 nm)

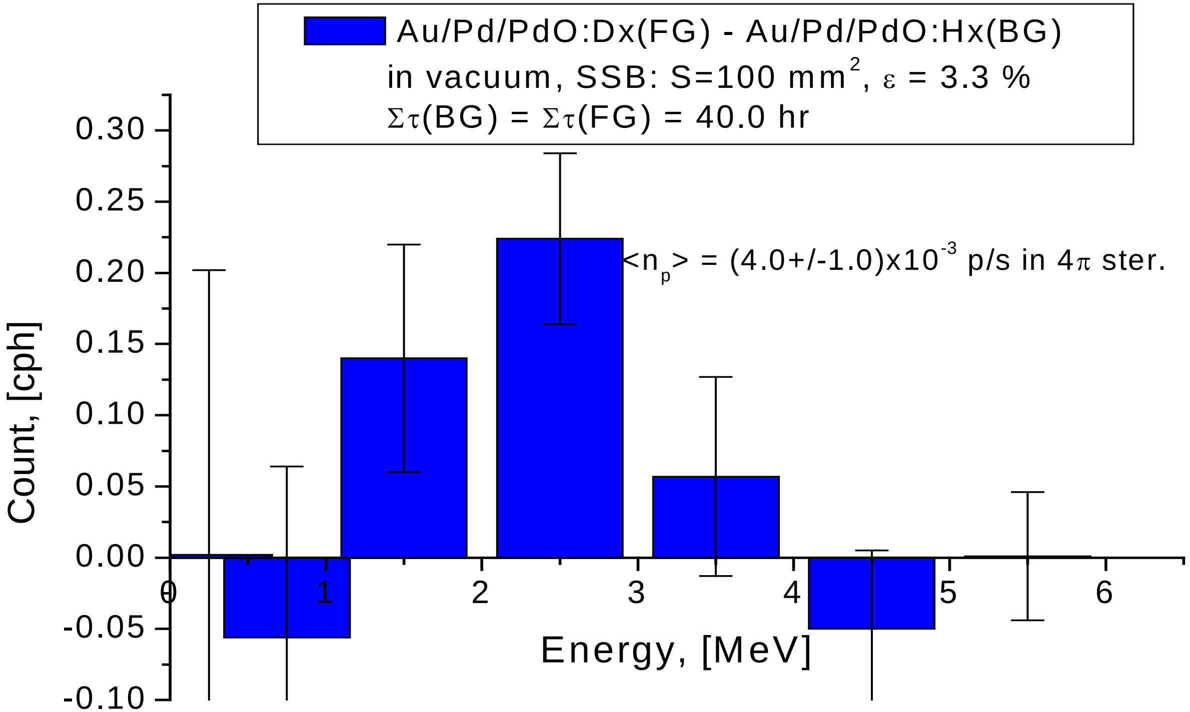
Typical charged particle background in vacuum (t=8 days in a row), A.G. Lipson et al., Fusion Tech, **38**, 238 (2000). Au/Pd/PdO pristine sample is in front of the SSB-1 (d=15 mm)



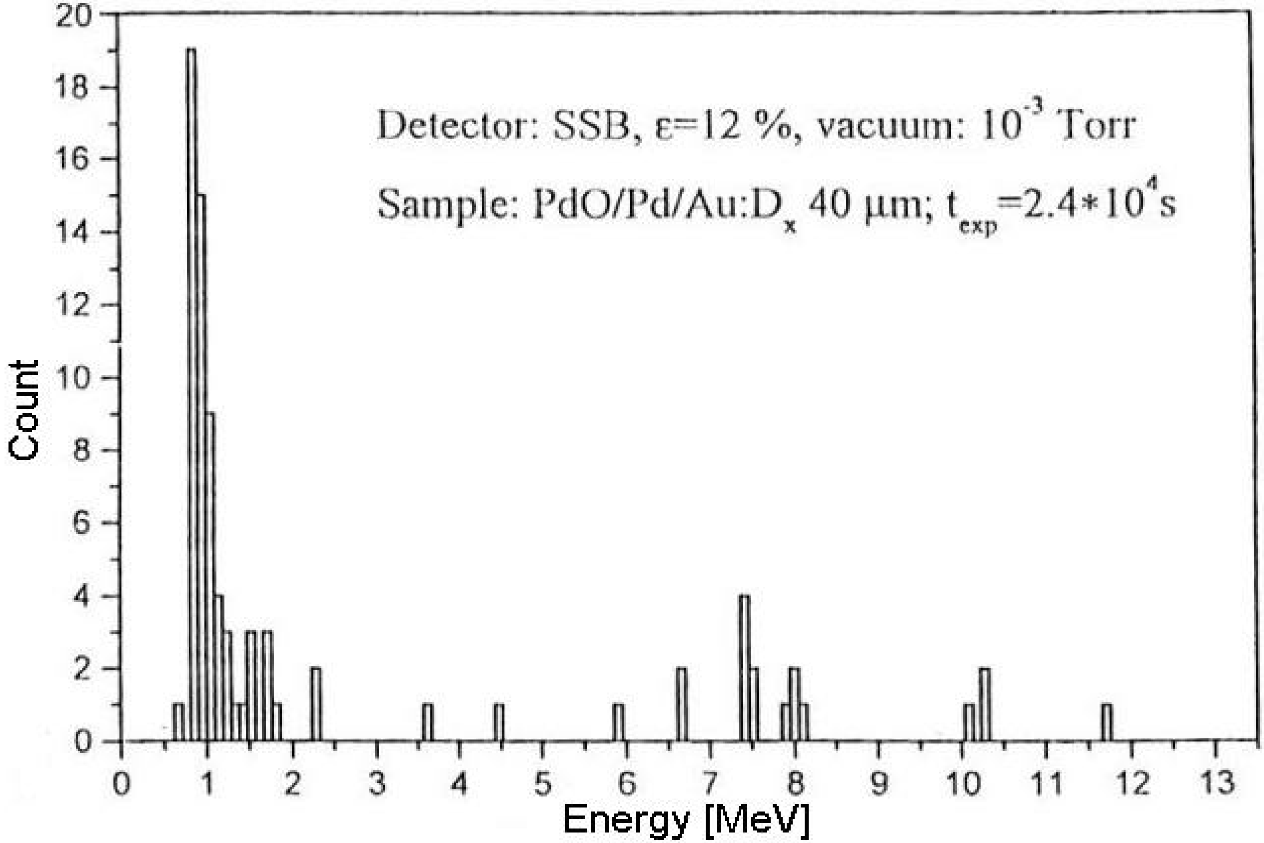
Au/Pd/PdO:Dx after the electrolytic D-loading. Sample is in front of Detector (d=15mm). Foreground run, SSB detector efficiency 3.3 %



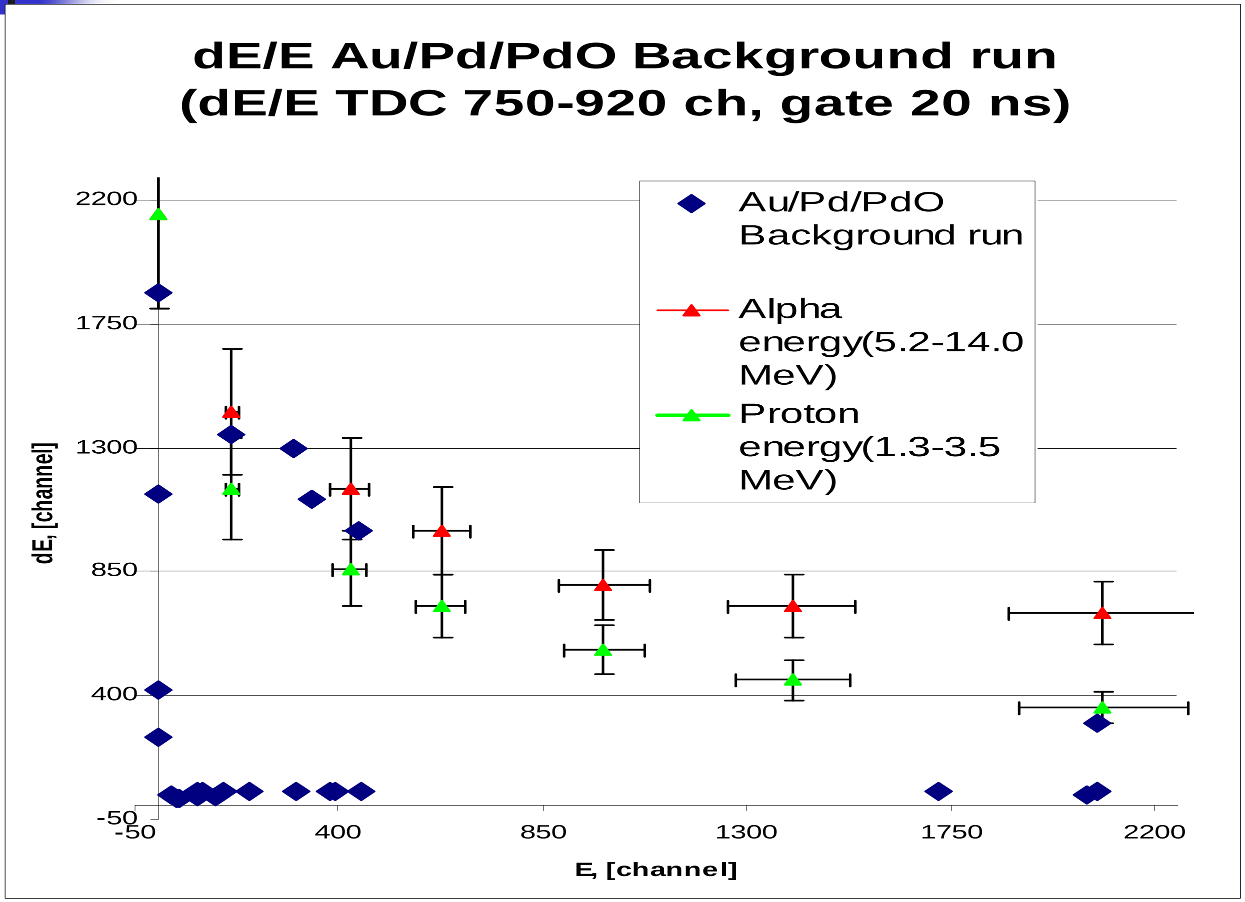
Weak spontaneous DD-proton emission from Au/Pd/PdO:D_x in vacuum (after electrolytic D-loading) SSB-1 data

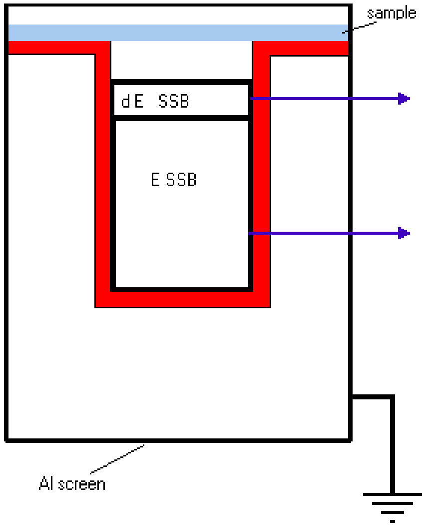


Large area high efficiency SSB-2 detector: S=900 mm^2, ε =12.0 %. Foreground run. The counts with E > 8.0 MeV are collected for a shorter time than that with SSB-1.

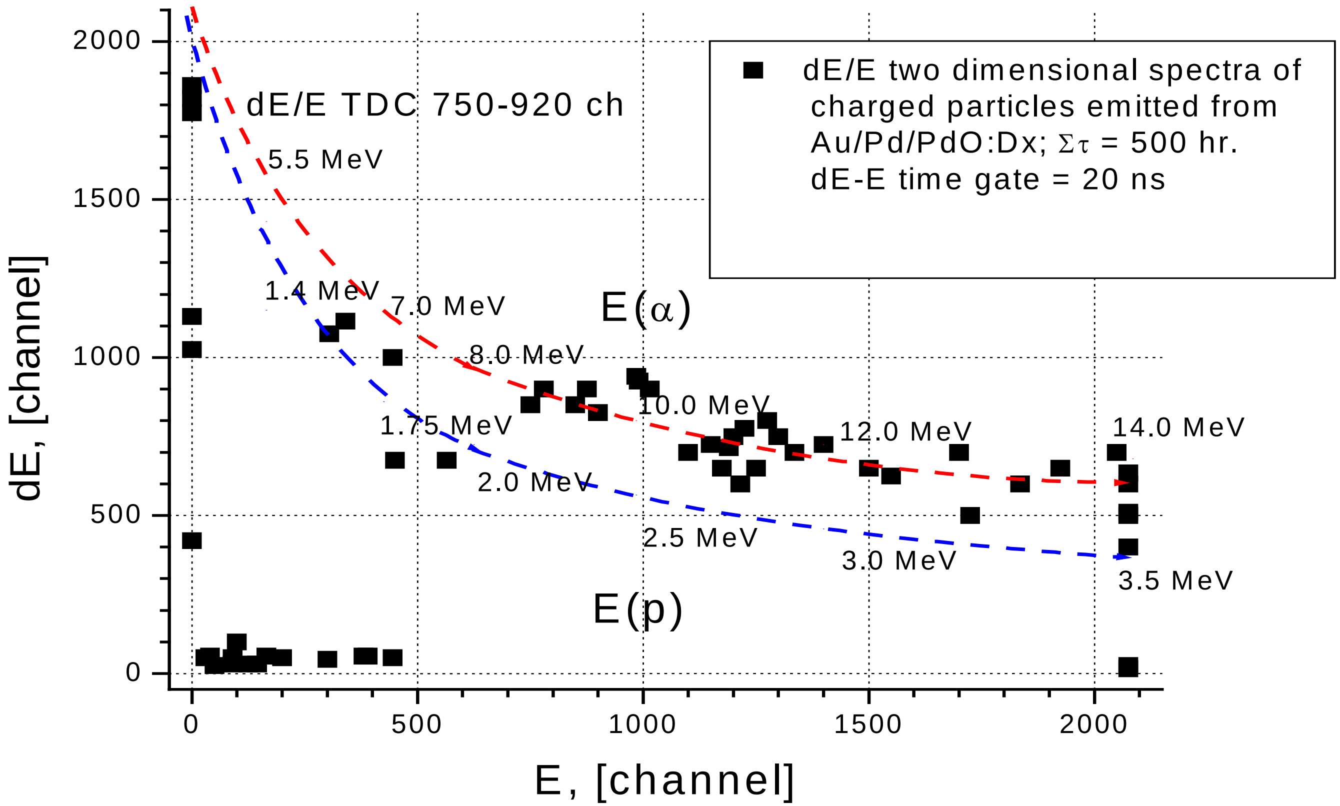


dE/E Background spectra of charged particles from pristine Au/Pd/PdO sample: $\Sigma\tau$ = 500 hr. The sample is in front of dE detector (d=10 mm).

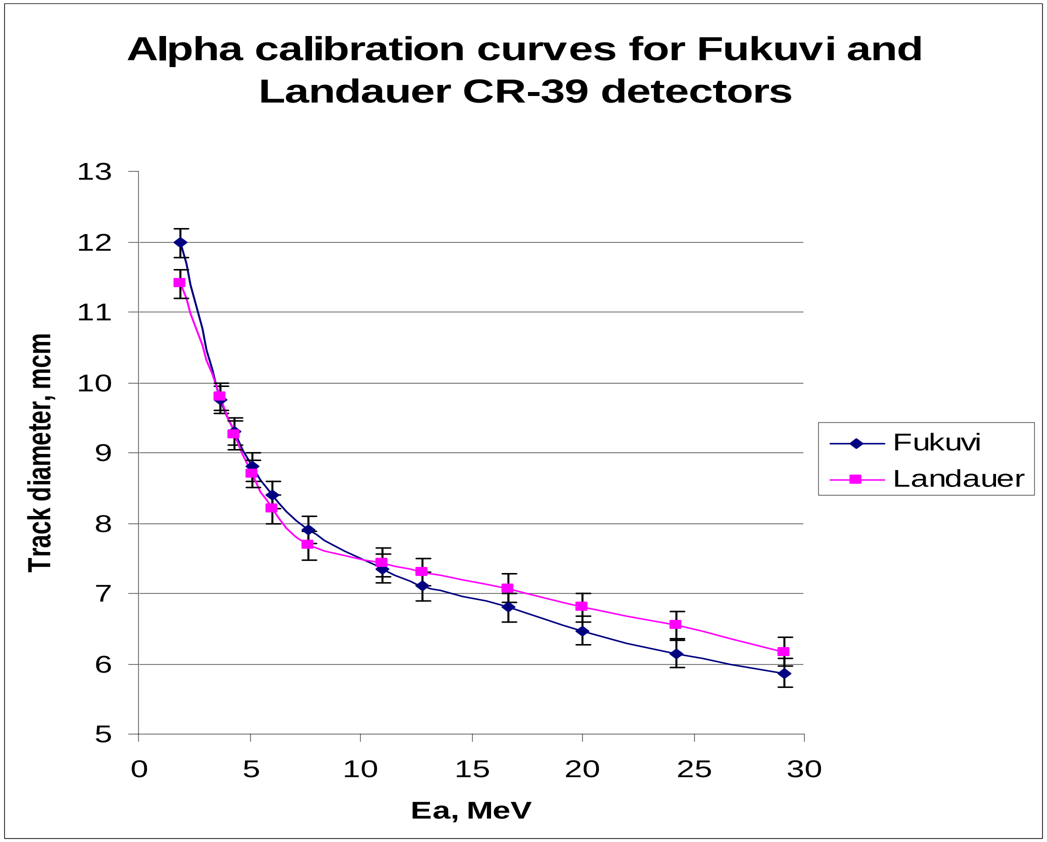




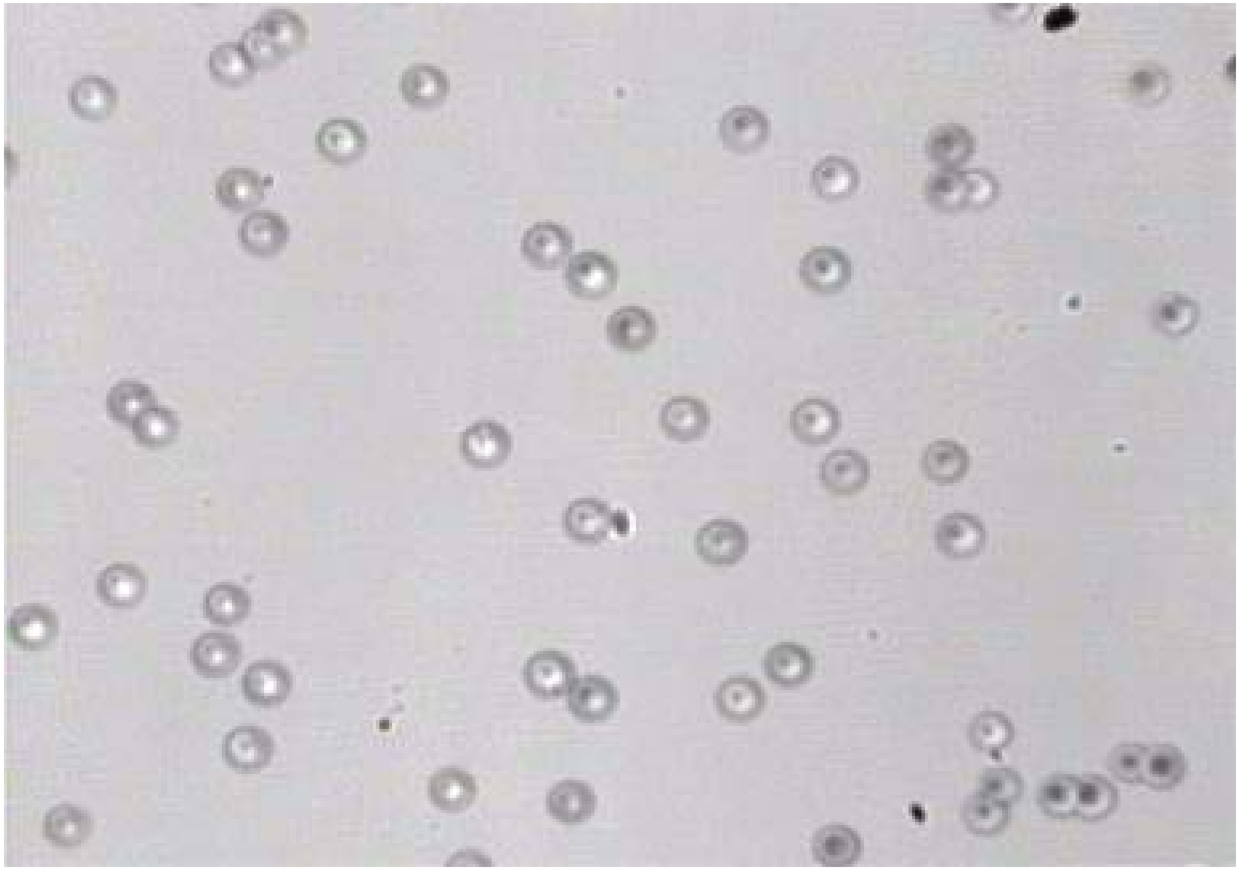
dE/E (SSB: dE=20μm, E=100 μm) 2-dimensional spectra of charged particles from Au/Pd/PdO:D_x (after electrolysis): $\Sigma\tau$ = 550 hr.; $<N_\alpha>$= $(6.4\pm1.2)\times10^{-4}$ [s^{-1}] in 4π ster.



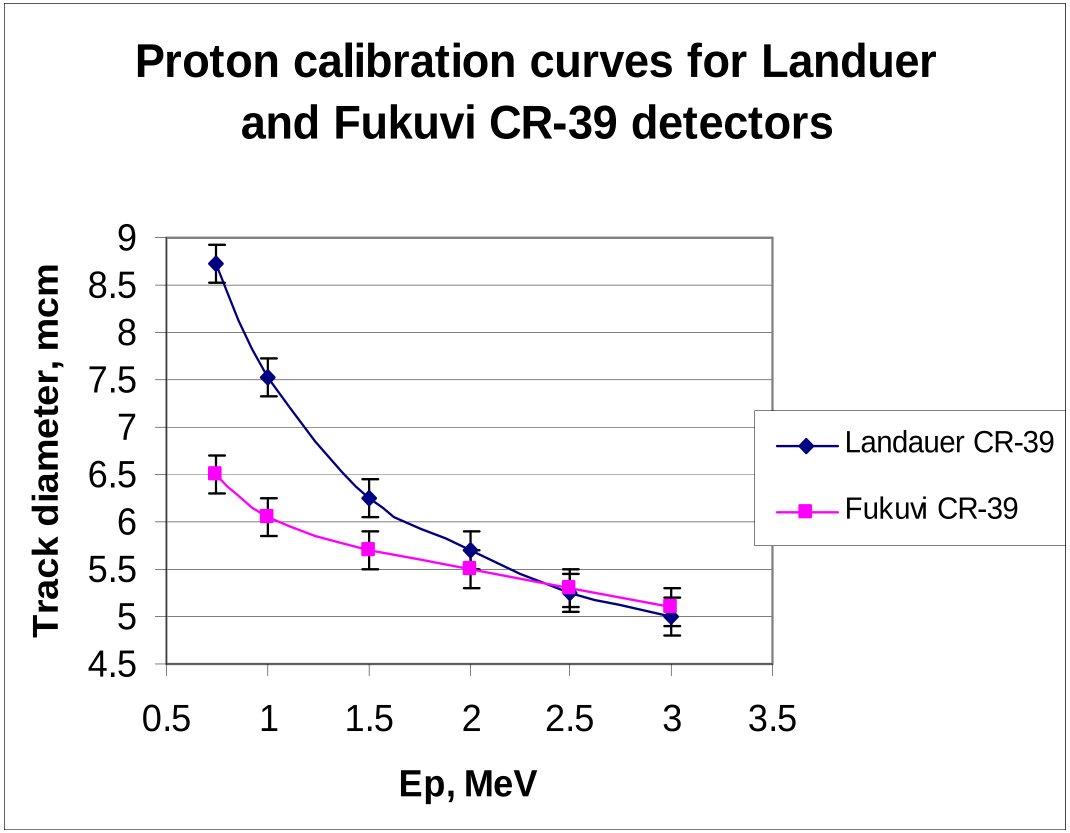
Alpha-sources and Cyclotron alpha beam calibration (2-30 MeV) of CR-39



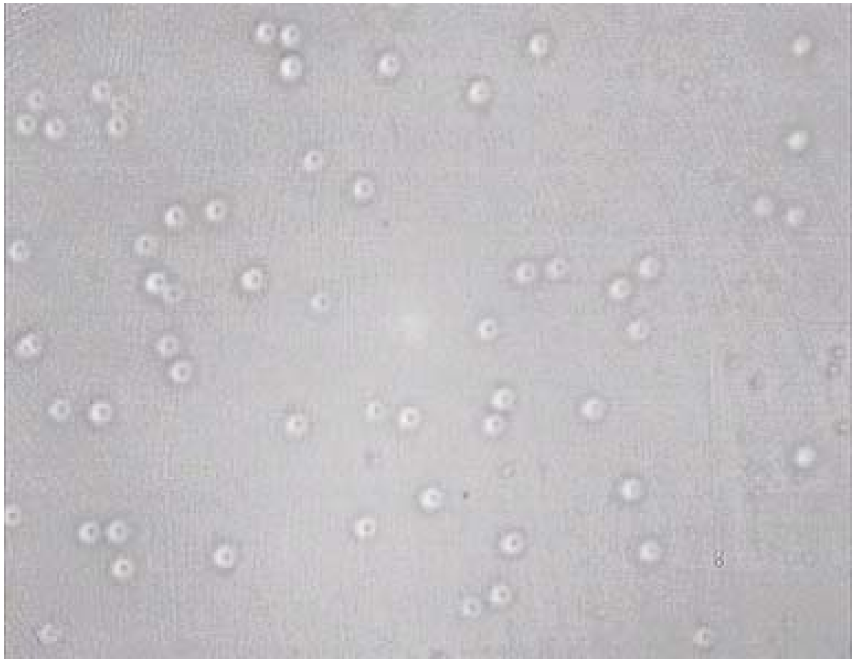
Tracks from 11.0 MeV α-beam @ normal direction with respect to CR-39 (Landauer) target: image area S= 0.12x0.09 mm



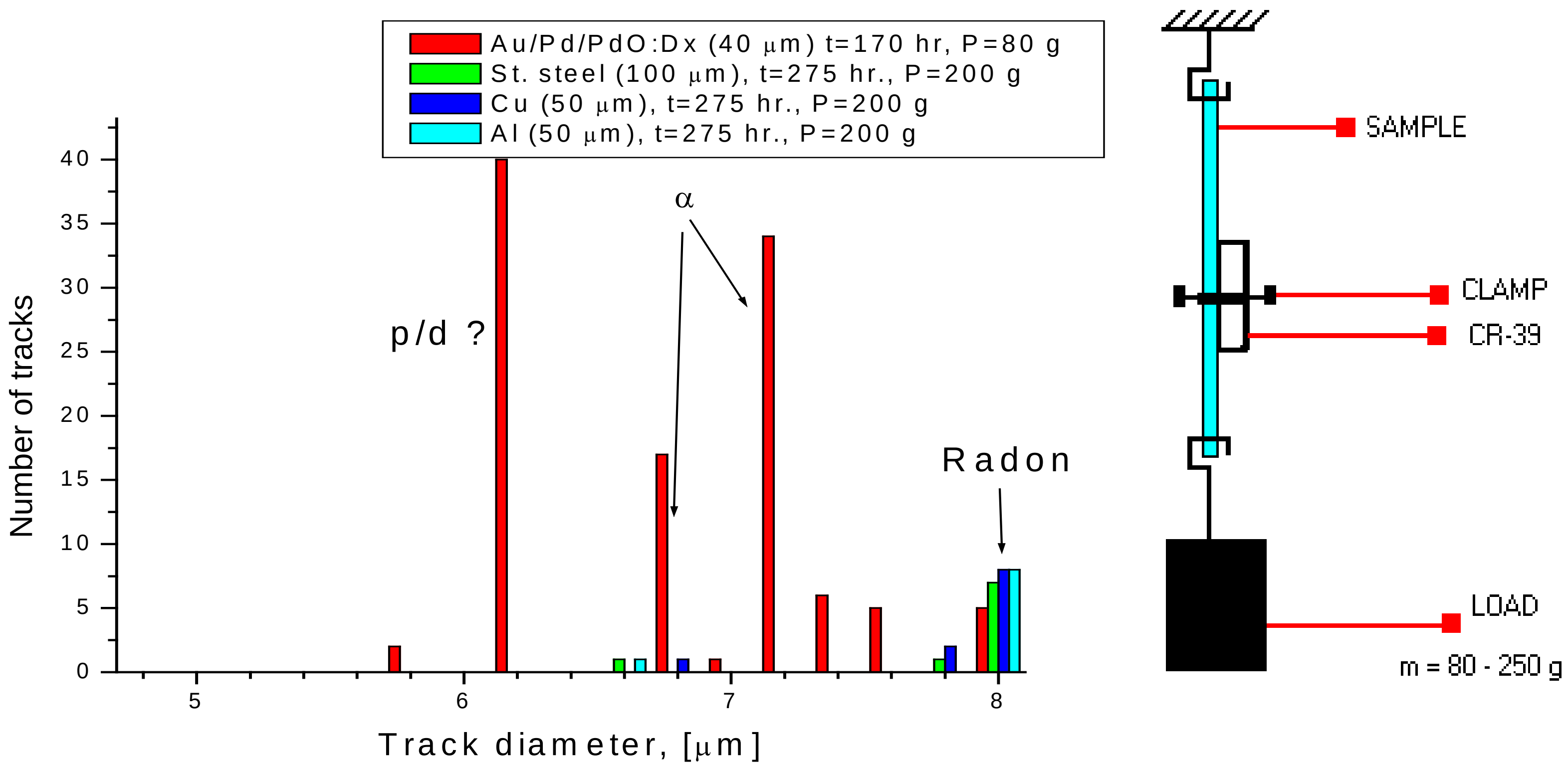
Proton Calibration with Van-DeGraaf accelerator (0.6-3.0 MeV) *calibration was sponsored by Lattice Energy LLC



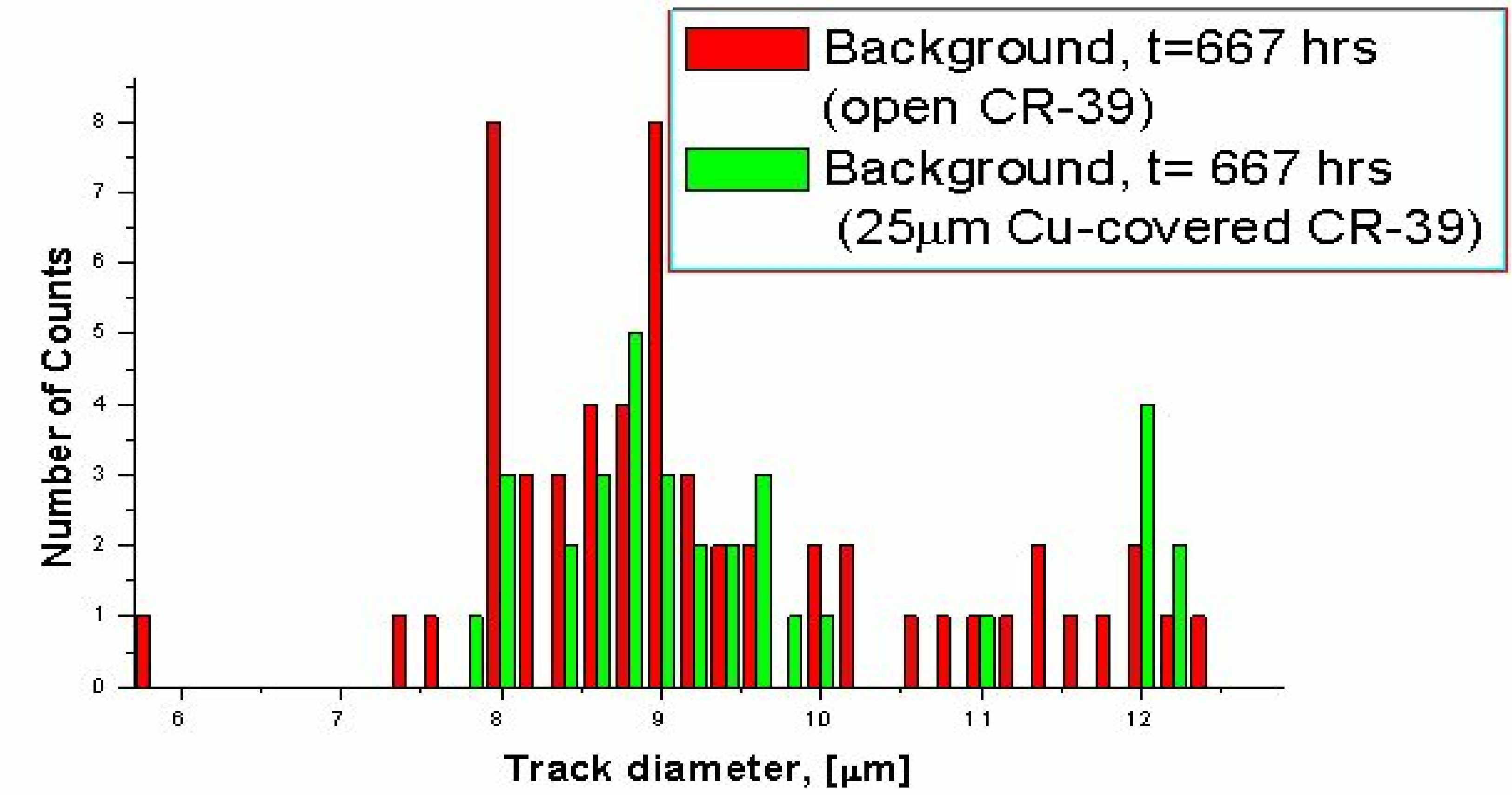
Tracks from 2.5 MeV p-beam @ normal direction with respect to the CR-39 (Landauer) target: image area S= 0.12x0.09 mm



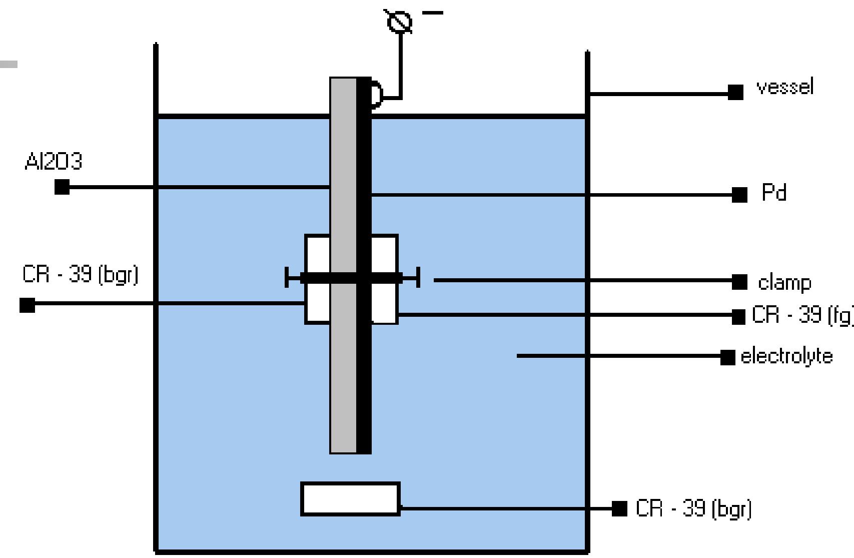
CR-39 data on EPC emissions (8<E_α< 16 MeV) in Au/Pd/PdO:Dx (after electrolytic D-loading): <N_α> = (5.6 ± 0.5)x10^{-4} [s^{-1}-cm^{-2}] 4π ster. Compare with dE/E

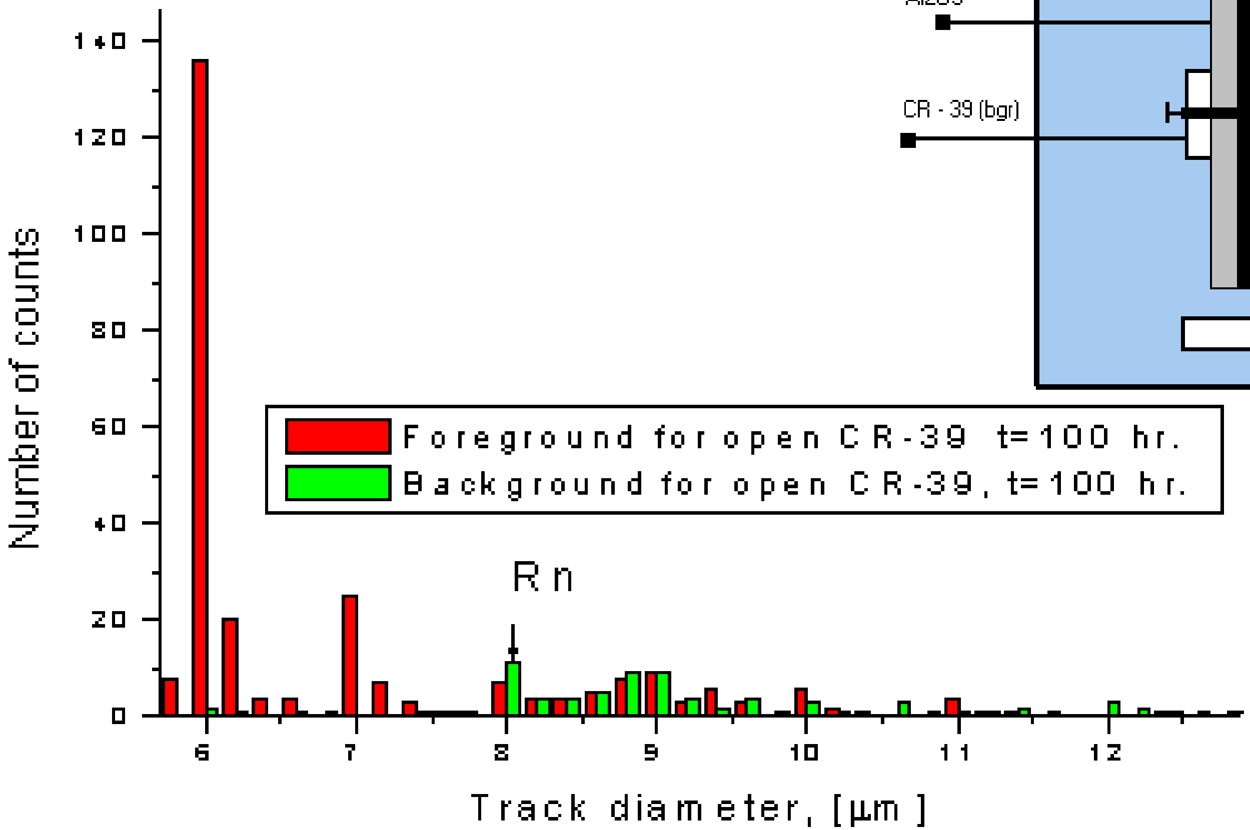


Open and Cu-shielded CR-39 Background Data

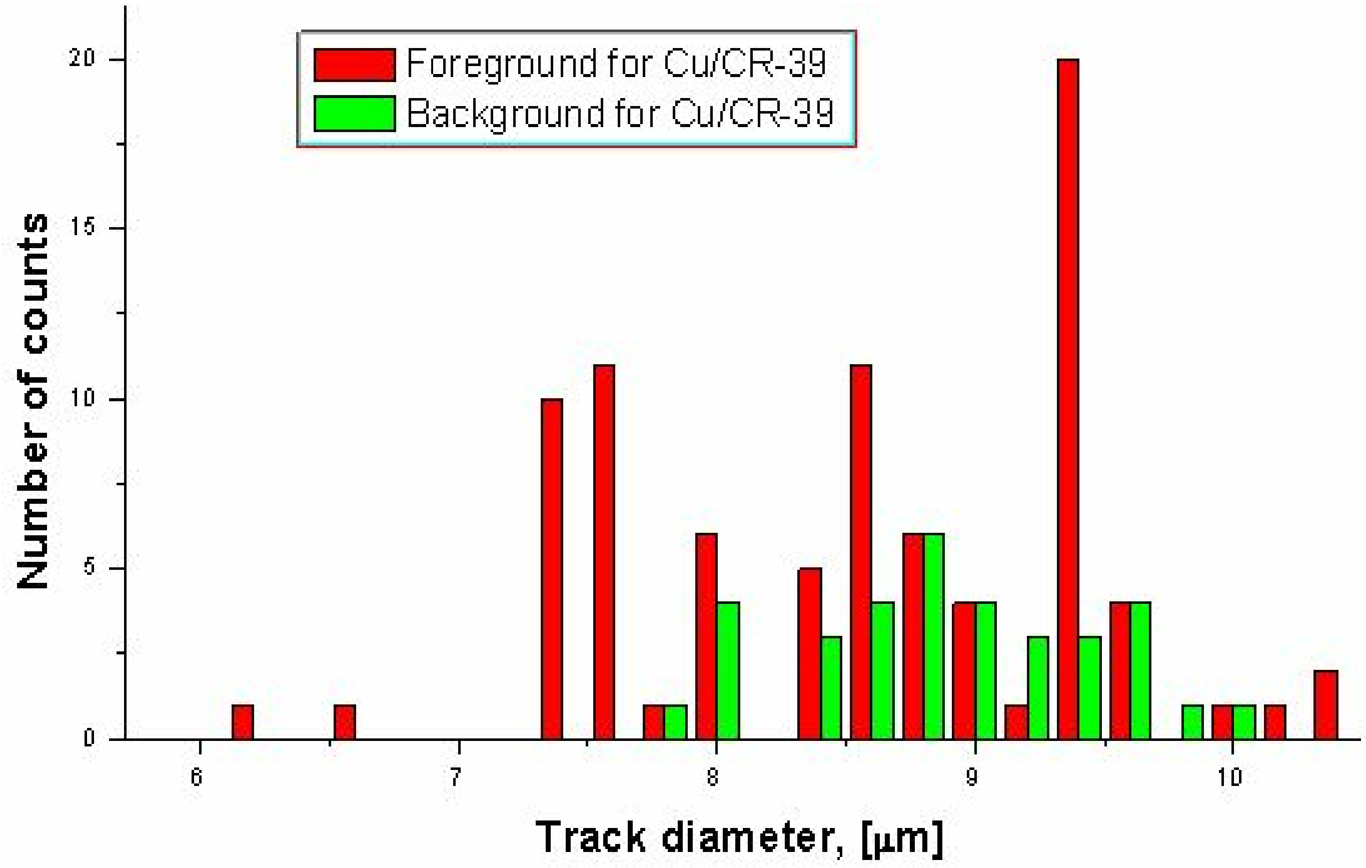


Histograms of track distributions with open CR-39 detectors: Pd/Al_2O_3 cathode in-situ electrolysis

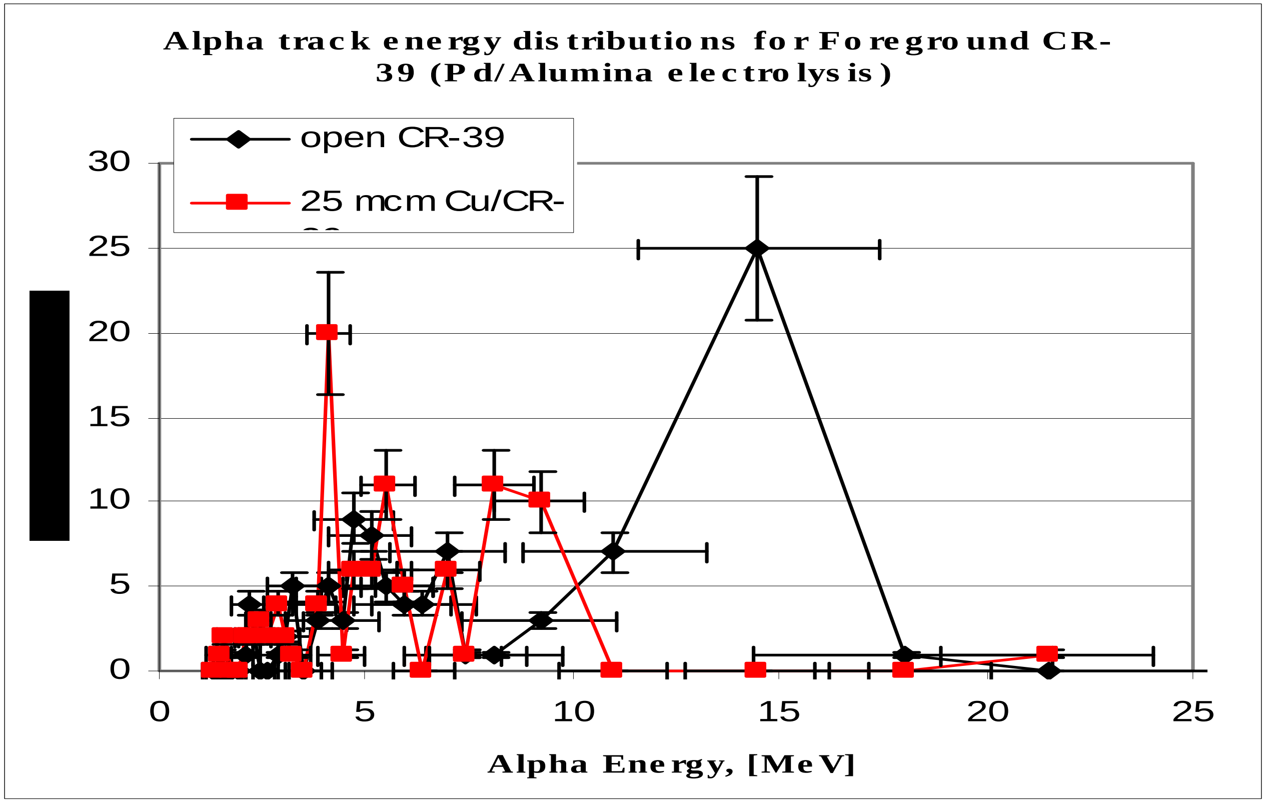




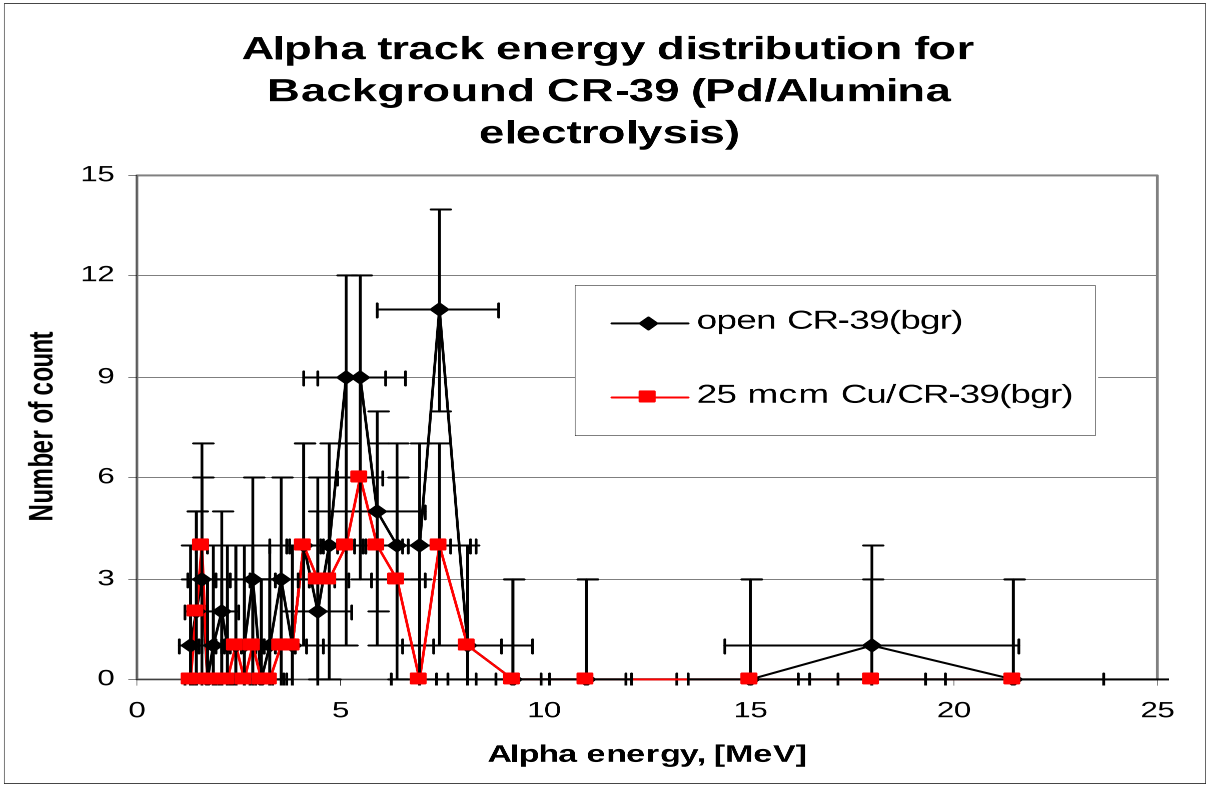
Histograms of track distributions with 25 μm Cu-shielded CR-39 detectors: Pd/Alumina cathode, in-situ electrolysis.



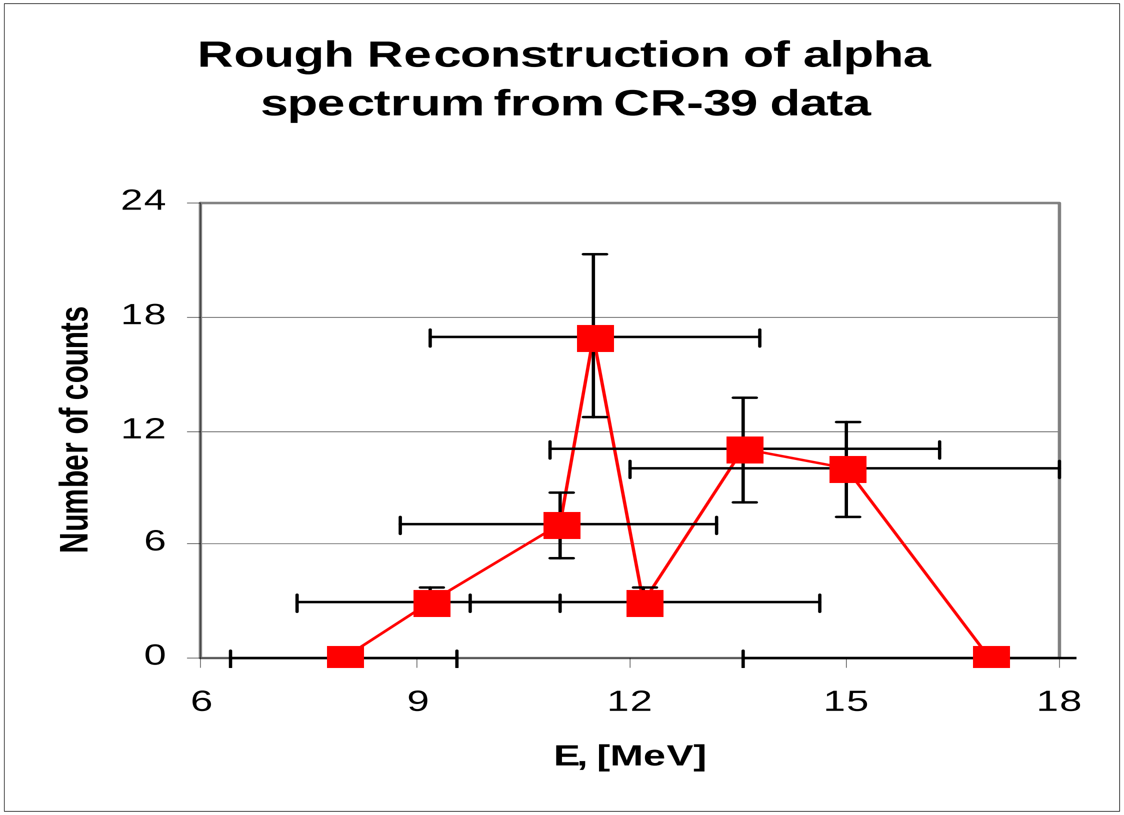
Foreground alpha energy distributions for open and Cu-shielded CR-39 detectors: Splitting of alpha “peak” in shielded CR-39 detector:



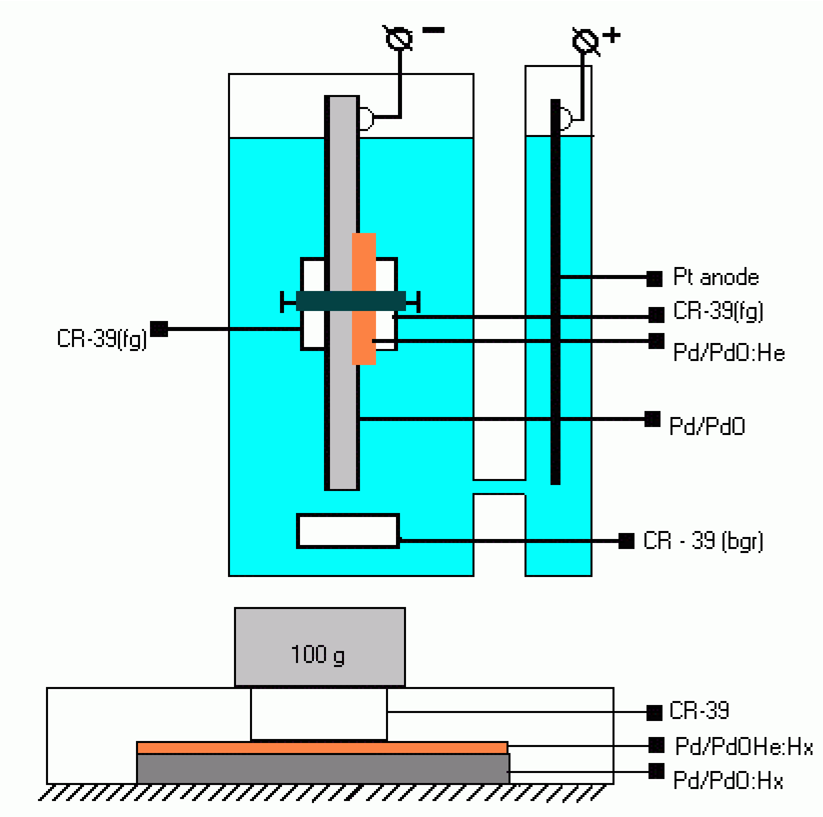
Background Alpha energy distributions for open and 25 μm Cu shielded CR-39 detectors



Possible Alpha spectrum with Background subtracting

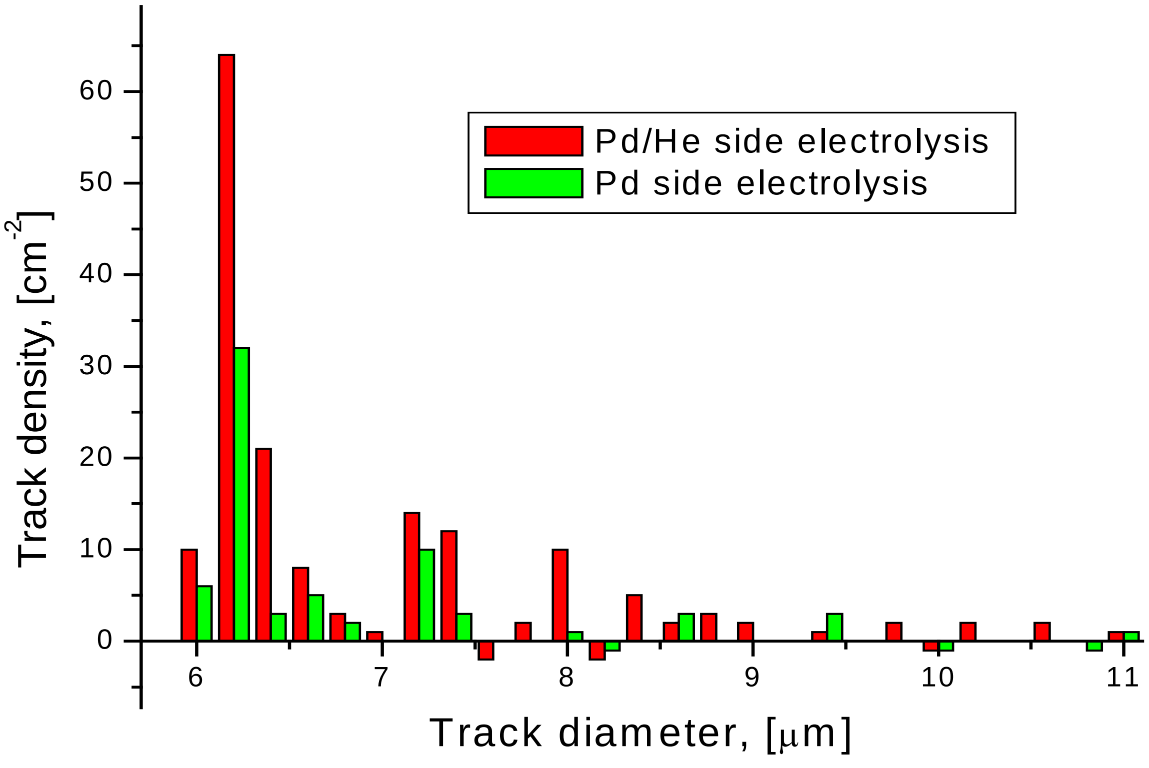


Electrolysis and posteffect with a double Pd/PdO-Pd/PdO:He cathode

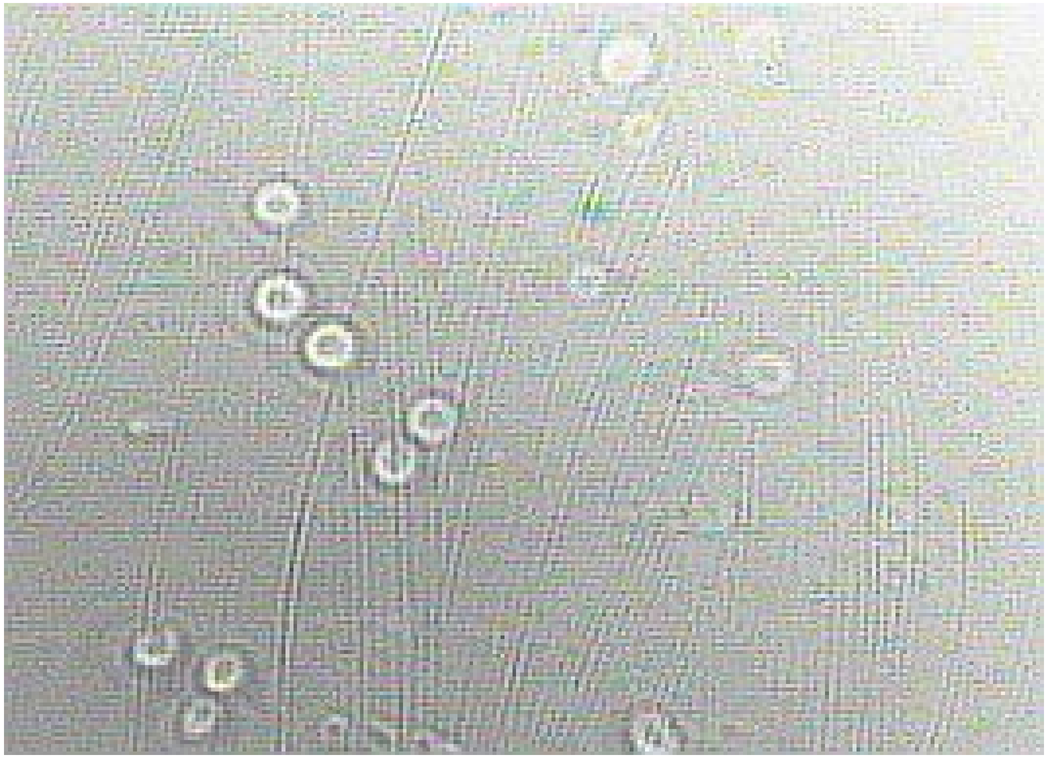


Typical Background in 1M-Li_2SO_4/H_2O electrolyte: CR-39 (Landauer) area S=120x90 μm^2

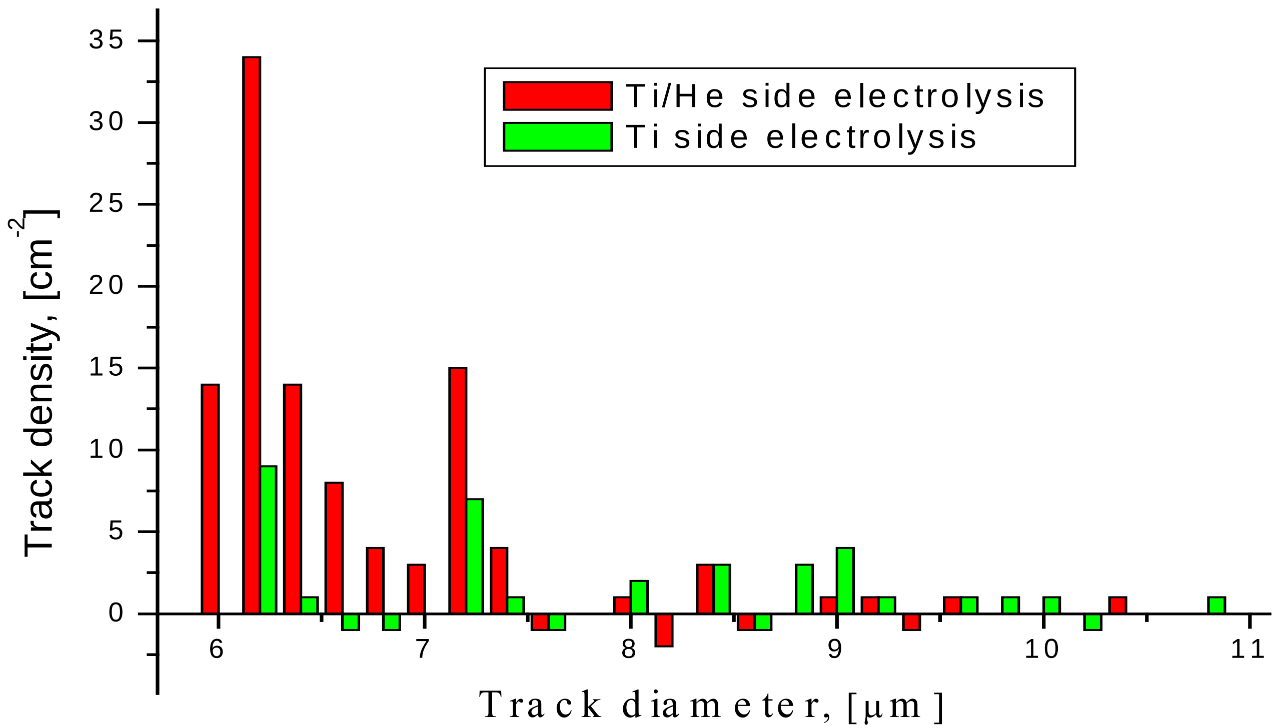
Comparison of ECP emissions from Pd:He and Pd sides of the cathode (with the background subtracting): Enhancement: k_α = 3.5, k_p =2.0



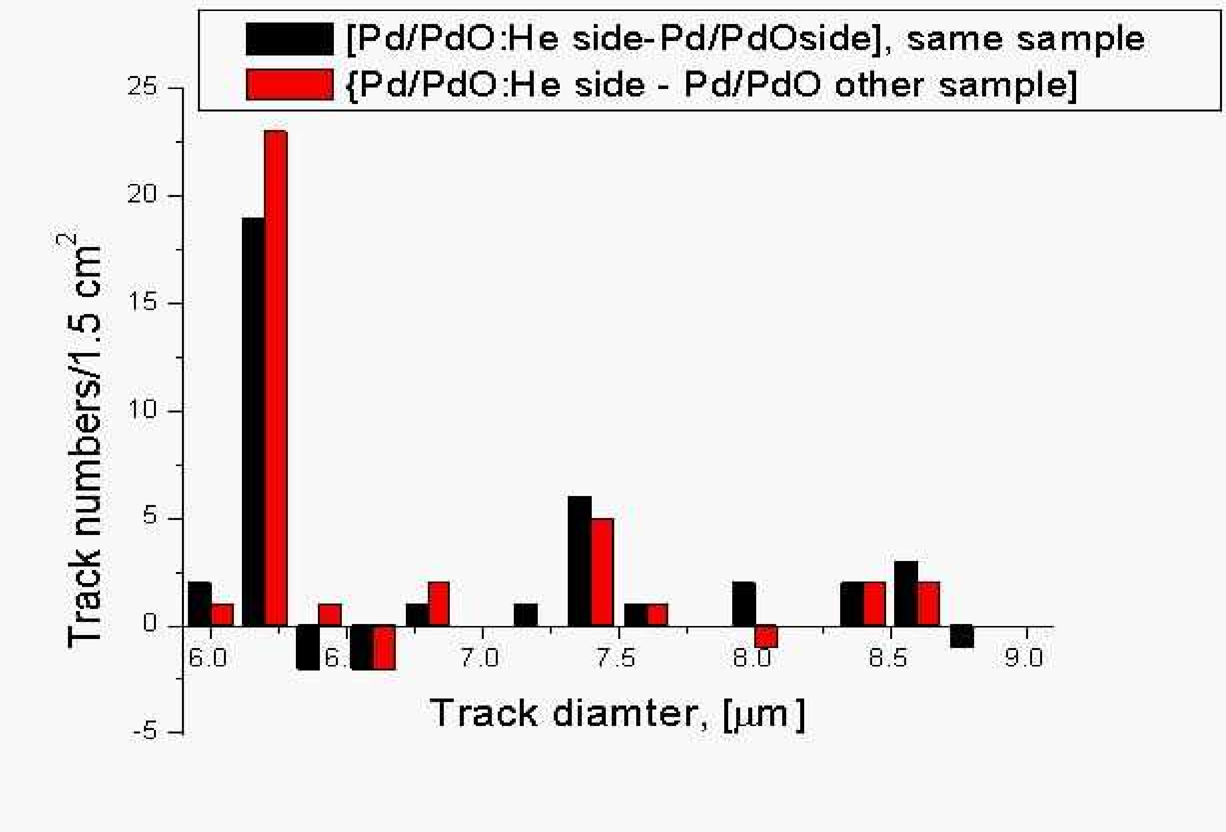
Group of energetic alphas (d=7.2-7.4 μm): Pd/PdO:He electrolysis: 100x100 μm^2 spot (negative image)



Double Ti:He/Ti cathode data (with the Background subtracting), Enhancement: k_α = 3.0, k_p =8.0



Comparison of ECP from Pd/PdO:He and Pd/PdO sides during exothermic H-desorption, t=5.0 hr.



Conclusions I

- Statistically significant number of energetic alphas in the range of 9-16 MeV was detected both with SSB and CR-39 track detectors techniques.
- Energetic alpha-particles accompanied by 1.7/2.8 MeV protons/deuterons are detected only in hydrogen/deuterium loaded metallic targets with a large “affinity” to hydrogen (Ti and Pd).

Conclusions II

- No ECP emissions were found either in the "cosmic" Background or from the materials with a low hydrogen solubility: Cu, Al, St. steel, Al_2O_3 (electrolysis), Ta(GD).
- ECP is a surface phenomenon, independent of sample thickness. (proof that it is not induced by Background "cosmic" rays).
- ECP emissions in Pd and Ti could be enhanced by He-4 ion implantation into a near-surface layer.

Possible mechanism speculations

- Applied energy focusing/concentration in some specific lattice sites near surface (the sites of a high internal strain ?).
- Coherent energy transfer from DD-reaction sites to the light nuclei (P.L. Hagelstein).
- Effective acceleration of these nuclei (p, d and ^4He) by intratomic electric fields.
- ECP emissions suggest anomalous energy release via the “active” lattice sites of non-equilibrium metal deuterides/hydrides

Further Information:

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1. A.G. Lipson, A.S. Roussetski, A. Takahashi and J. Kasagi: "Observation of long-range alpha-particles during deuterium/hydrogen desorption from Au/Pd/PdO:D(H) heterostructure", Bulletin of the Lebedev Physical Institute (Russian Academy of Sciences), **#10**, 22-29 (2001).
2. A.G. Lipson, G.H. Miley and A.S. Roussetski, "Energetic alpha and proton emissions on the electrolysis of thin-Pd films", Trans. Amer. Nuclear. Soc., **88**, 638-641, (2003).
3. A.G. Lipson, A.S. Roussetski, G.H. Miley and E.I Saunin, "Phenomenon of an energetic charged particle emission from Hydrogen/deuterium loaded metals", Proc. ICCF-10, 24-30 August, Cambridge, MA, 2003