Evidence for Fast Neutron Emission During SRI's SPAWAR/Galileo-Type Electrolysis Experiments #7 and #5, Based on CR-39 Track Detector Record

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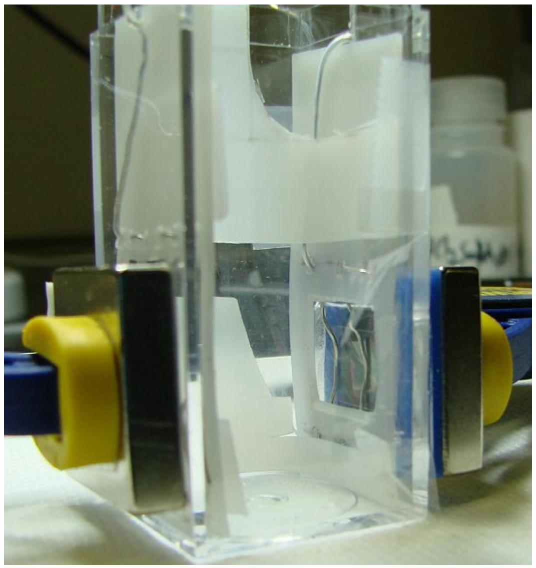
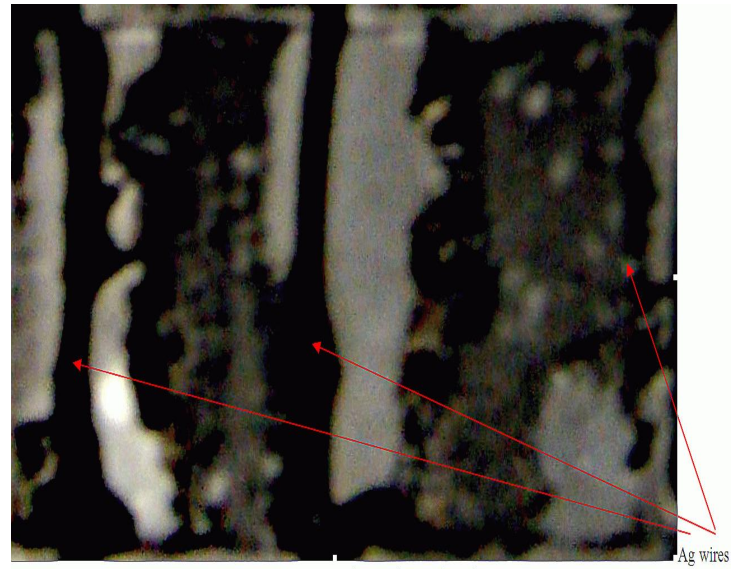
Objectives

- Verify reported nuclear emissions using Pd electrodeposition technique and CR-39 detectors (P. Boss *et al*).
  - Ag(or other metal)-wire cathodes
  - 10^7-10^8 pits/cm^2 where the cathode meets the CR-39.
  - Identify pits caused by mechanical defects - electric discharge
- Test the applicability of our track identification technique (A. Roussetski et al, ICCF-12, Yokohama, 2005)
  - successive etching of CR-39
  - plot track diameter evolution vs. removed depth
- Simultaneous CR-39 exposure and in-situ neutron detection.
  - Compare Live (D_2O) to Blank (H20)
  - Compare Background (CR-39 2m from cell) to Foreground
  - Compare to BF_3 proportional detector count rate.

Electrolytic cell and detector placement





BE010-5 CR-39 and wires during electrolysis

- Cr-39 detector in runs #7 and #5 were separated from the cathode and electrolyte by sheets of 6 μm Mylar® and 60 μm polyethylene, respectively.
- BF_3 spherical neutron dosimeter with low self-efficiency $\varepsilon_s = 2.5\times10^{-3}$ (Cf-252)
  - Statistically significant (neutron?) counts were detected at SRI during the runs

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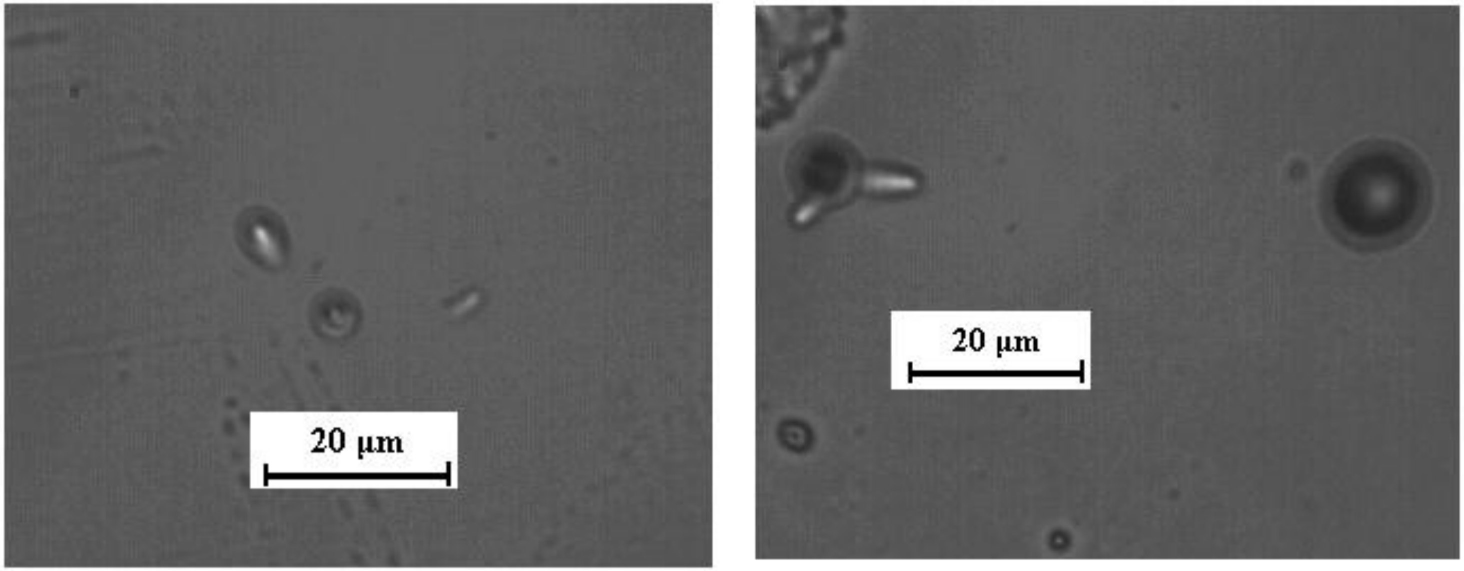
CR-39 treatment and reading

- All CR-39 detectors were cut from the same sheet.
- Etched for 6.5 hours in 65°C 6.5M NaOH after electrolysis.
- Etched three more times, for approximately 7, 14 and 21 cumulative hours in 6M NaOH at T=70 °C ($v_b \approx 1.3$ μm/hr).
- Used the "PAVICOM" track reading facility in Lebedev Physics Institute, Russian Academy of Sciences, Moscow to read the detectors after each etch.
- Pit distributions at the surface of etched #7 and #5 detectors were compared with that of the blank CR-39 and the proton recoil tracks from a weak Cf-252 neutron source (I_n = 120 n/s)
- See Roussetski et al, Proceedings of the International Workshop on Anomalies in Hydrogen/Deuterium Loaded Metals, Catania, 2007 p. 182 (Catania Workshop)

Background 3alpha events, etch 7 hr



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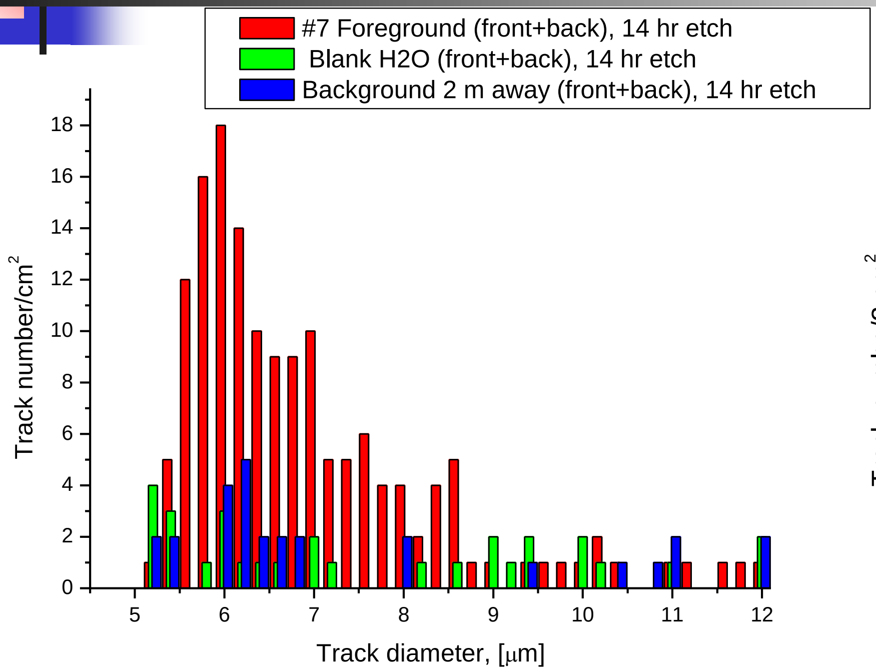
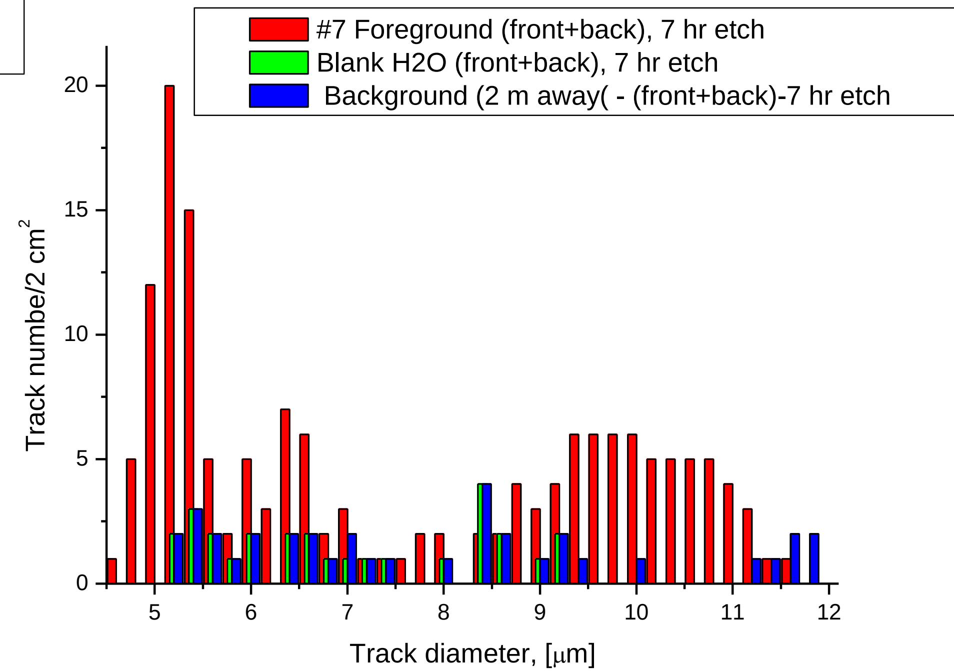
Neutron calibration results

- Proton recoil spectrum after 7 hr etch is at 4.5-9.0µm track diameter (maximum at 5.2µm)
  - Consistent with 2.2-2.5 MeV (see Landauer's CR-39 proton calibration curve obtained with Van DeGraaf accelerator)
- Proton recoil spectrum after 14 hr etch is at 5.0-12.0µm track diameter (maximum at 6.0µm)
  - Consistent with 2.2-2.5 MeV proton track diameter gain at 14 hr etching compared to 7 hr etch.
  - The neutron detection self-efficiency of CR-39 at t = 14 hr ($\varepsilon_n \sim 1.2\text{x}10^{-4}$) is about factor of 1.3 higher than that at t = 7 hr($\varepsilon_n \sim 0.9\text{x}10^{-4}$) due to increase in proton recoil critical angles with the removed CR-39 depth.
- Raw data available in Catania Workshop Proceedings, p182

Comparison of Foreground #7 data (both sides) with CR-39 (H_2O electrolysis), Background after 7 and 14 hr etches. Blank and the Background show no sign of proton recoil from fast neutrons (no irradiation on shipping).





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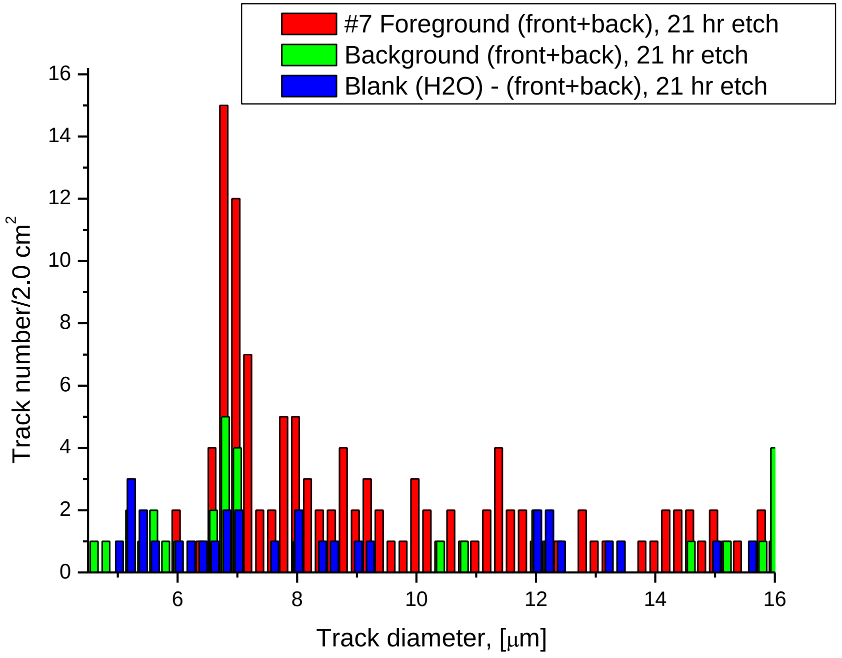
Comparison of Foreground #7 data (taken from both sides) with that from Blank experiment (H2O electrolysis) and the Background (detector is placed 2m away of the electrolytic cell) - 21 hr etch



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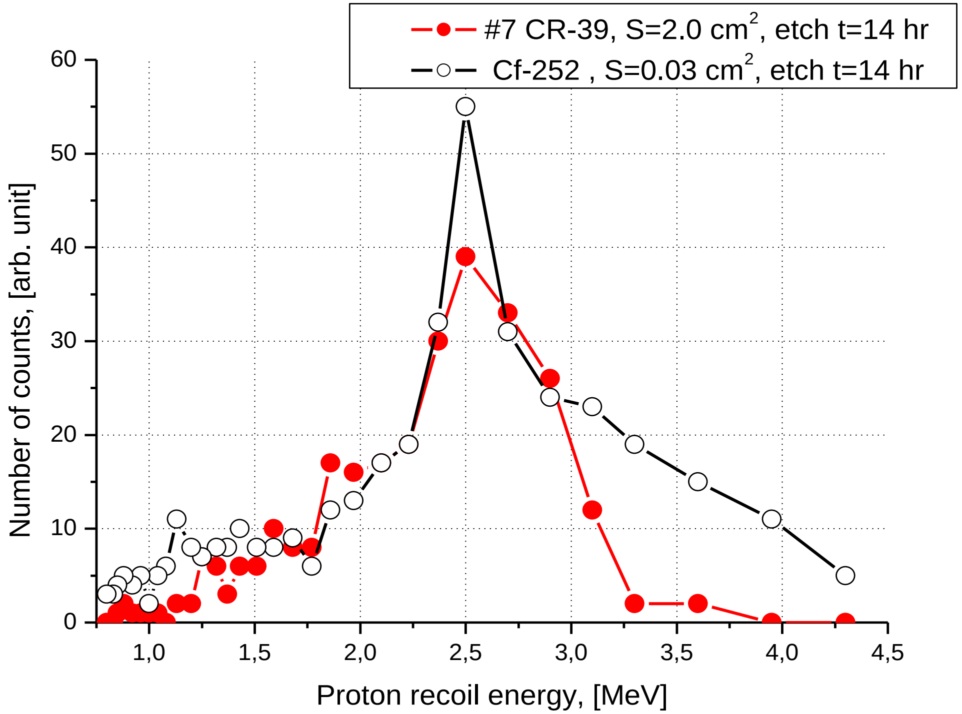
Rough reconstruction of the proton recoil spectra for CR-39 detectors obtained during run #7 and during exposure to Cf-252 neutron source using track diameter vs. proton energies and critical angle θ_c vs. proton energy plots



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Calculation of mean neutron emission rate:
I. For 7 hr etch time removed depth is 8.7μm

- Average foreground track density (<N(fg)>) is 58.5 cm^{-2}.
- Average background track density (<N(bg)>) is 6.0 cm^{-2}.
  - Both sides of Blank detector
- $\langle \Delta N \rangle = \langle N(fg) \rangle - \langle N(bg) \rangle = 52.5 \pm 8.0$ track/cm^2.
- Neutron count rate/intensity from cathode wire (I_n) is $2\langle \Delta N \rangle/(t \times \varepsilon_s)$
  - $\varepsilon_s = 9.2 \times 10^{-5}$ (CR-39 self-efficiency at t_{etch}=7 hr)
  - t is the Foreground electrolysis time.
- If the neutrons were emitted when the current > 0.5 mA (t = 15 days), I_n = **0.90 ± 0.14 n/s**
- If the neutrons were emitted when the only when the BF_3 counter read high (Δt = 4 days) **I_n = 3.38± 0.53 n/s** I
- Hence, the neutron emission rate in the run #7 can be estimated in the range of 1.0-3.0 n/s.

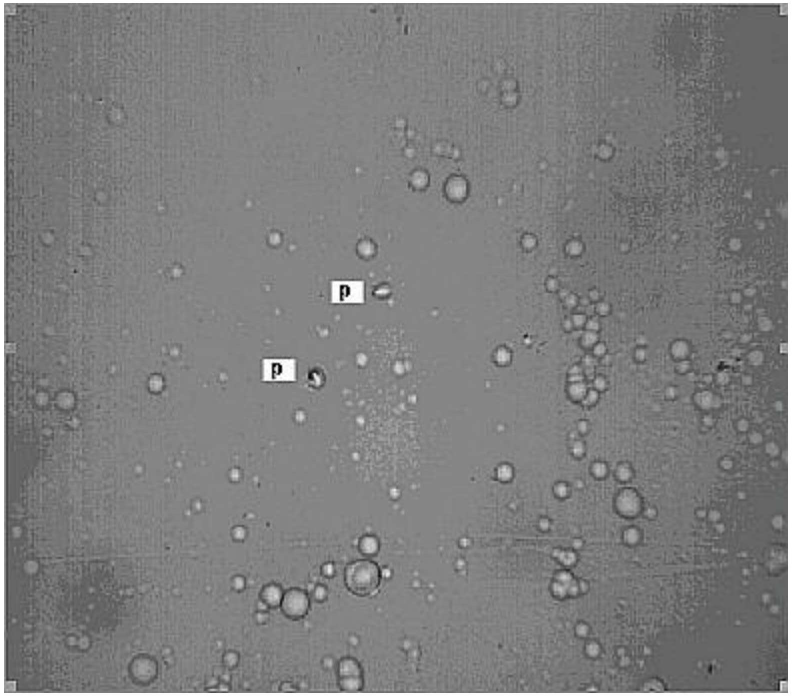
Calculation of mean neutron emission rate:
II. For 14 hr etch time removed depth is 18 μm)

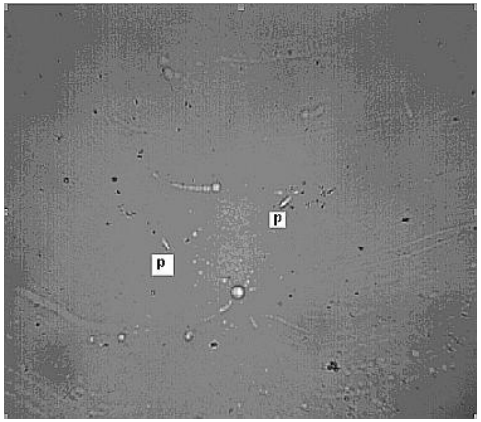
- Average track density at both sides of #7 CR-39 is <N(fg)> = 88 cm^{-2}.
- The Background track density at both sides of blank detector (S = 0.25 cm^2 each) is the <N(bg)> = 26 cm^{-2}.
- Accordingly to calibration measurements CR-39 at etch time tet = 14 hr the self-efficiency was found to be ε_s = 1.17 x10-4.
- Then, for t =15 days: $I_n = 2\langle\Delta N\rangle/(t \times \varepsilon_s)$ = **0.82 ± 0.14 n/s** in 2π solid angle and for Δt = 4 days **I_n = 3.08 ± 0.53 n/s.** Thus, the result for 14 hr etch gives approximately the same (within a standard deviation) neutron emission intensity range as that for a 7 hr.

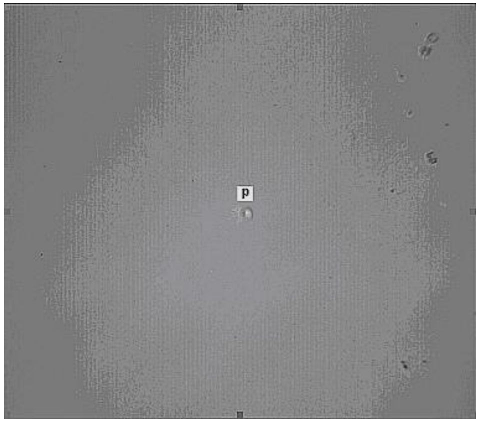
Summary of #5 detector results (Run #SRI BE010-5)

- The #5 CR-39 detector used in SRI BE010-5 PdD_x deposition electrolysis experiment had a 60 μm polyethylene film adhered to both faces while immersed in the electrolyte and in contact with the cathode.
- This detector showed confusing results. The front face was found to be covered with high density pits (defects) making it almost impossible to distinguish real nuclear tracks from defects.
- The rear face of #5 detector shows proton recoil tracks similar to those found on both faces of the # 7 CR-39 (with a track density 50 -70% of that of #7).

Proton recoil tracks on the front side of the #5 detector easily differentiated from the defect (“ground beef”) Background at t = 14 hr etch







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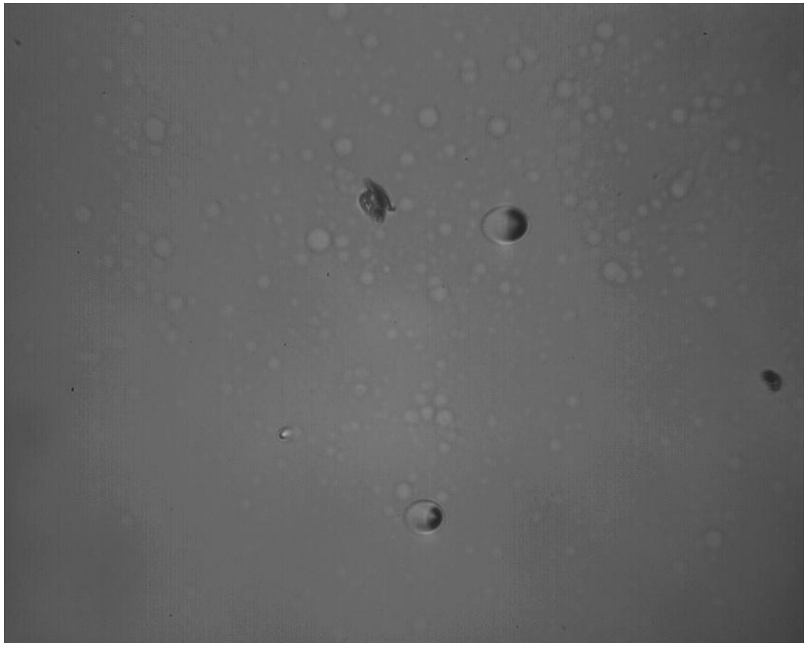
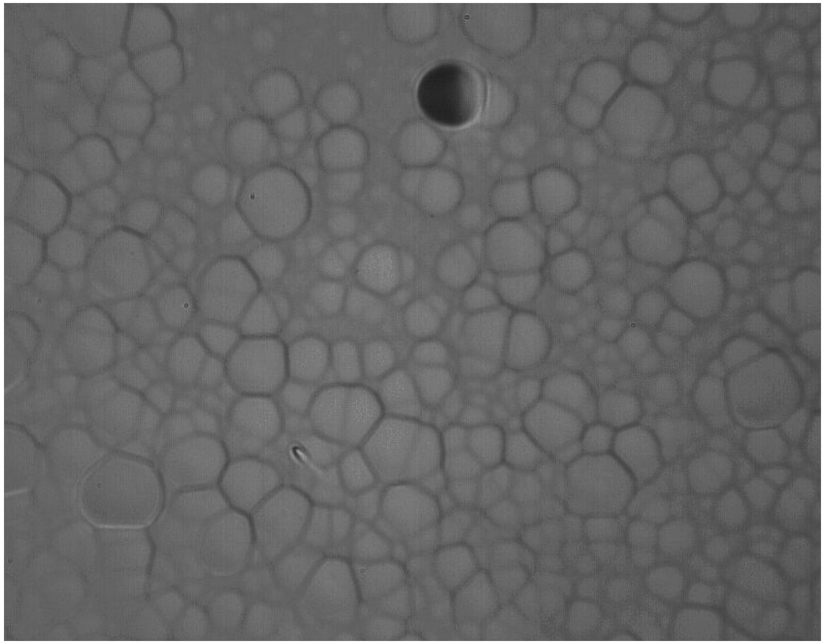
Images of the front side of #5 detector after 21 hr etch (nuclear tracks on top of “ground beef” Background)



$2\ \alpha\ +1p$



$1\alpha+1p$

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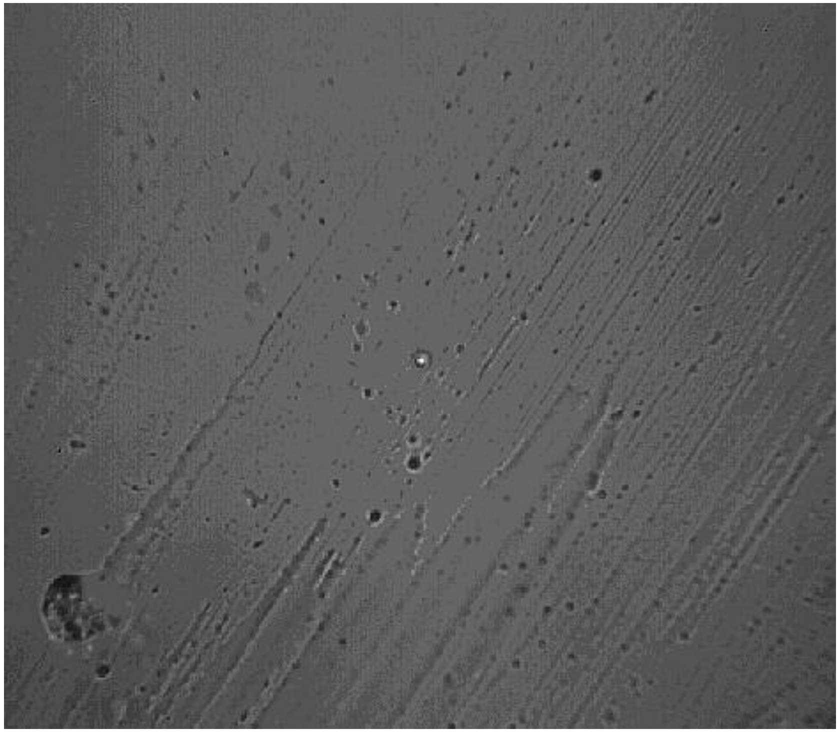
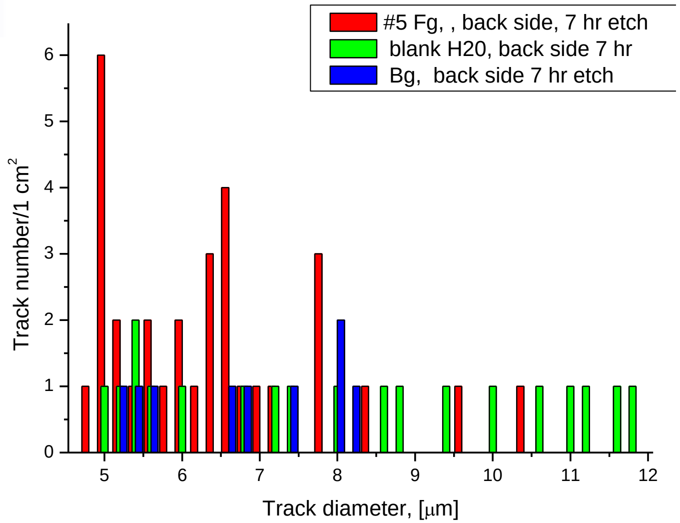
Typical images of the front side of #5 detector after extra 21 hr etch

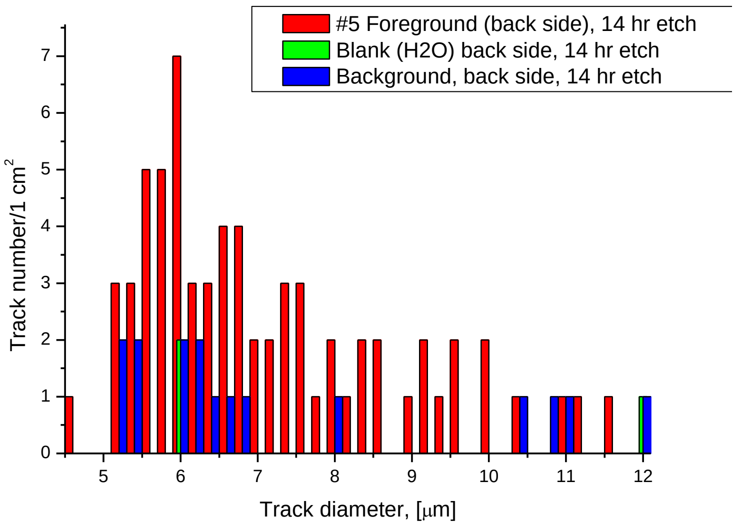
single oblique recoil protons

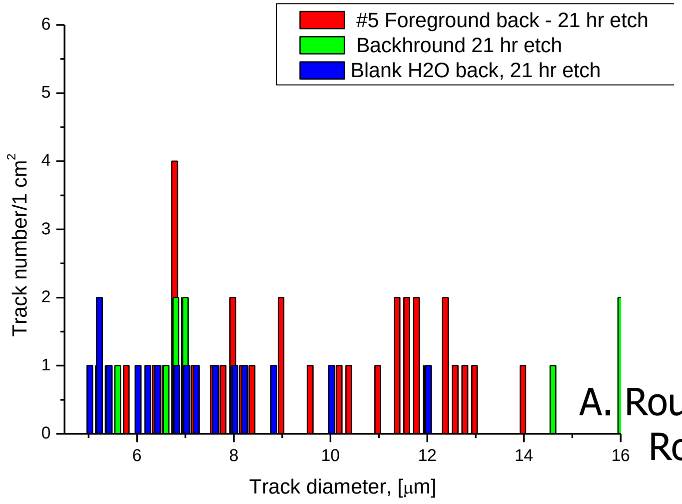


normal incidence recoil protons

Proton recoil tracks from the "clean" back side of #5 detector after 7, 14,and 21 hr etches







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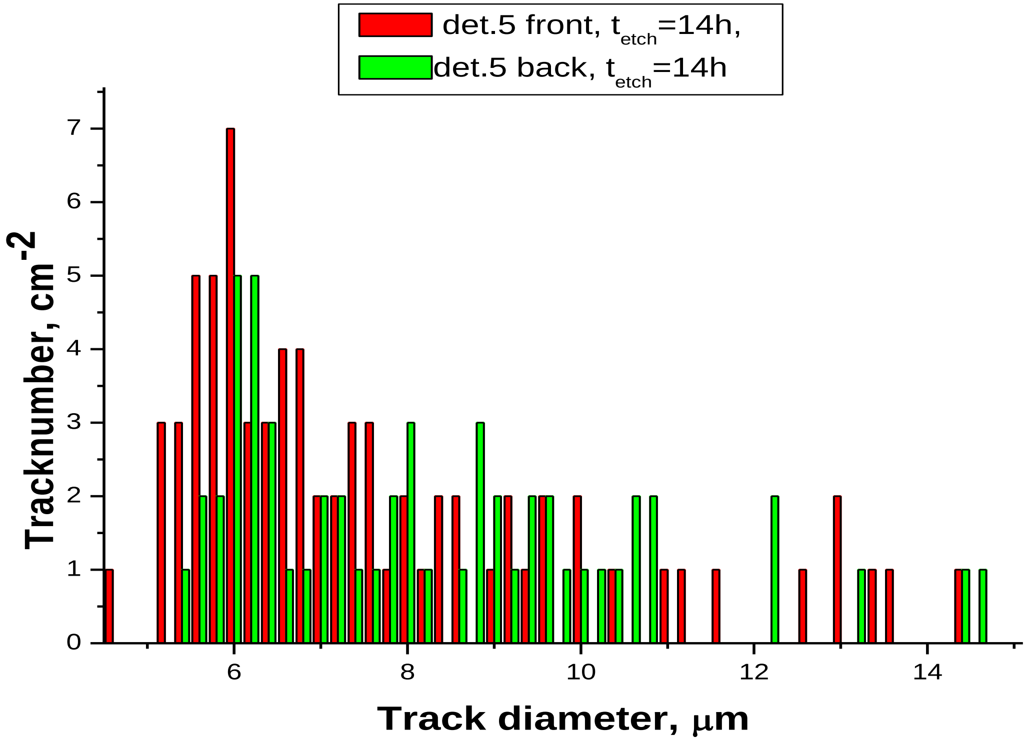
Comparison of the back and the front side proton recoil spectra at t = 14 hr etch



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Estimate of neutron emission rate taken for t =20 days of electrolysis in the run # BE010-5:

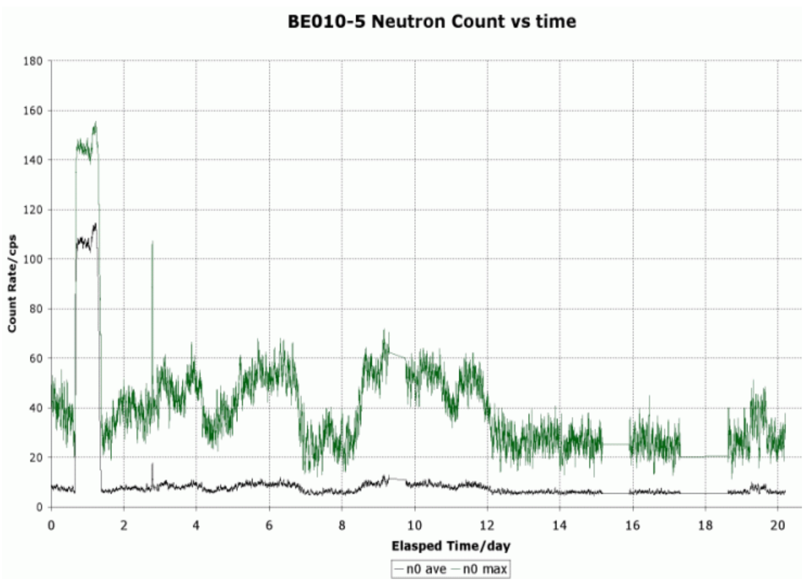
t ~ 7 hr etch

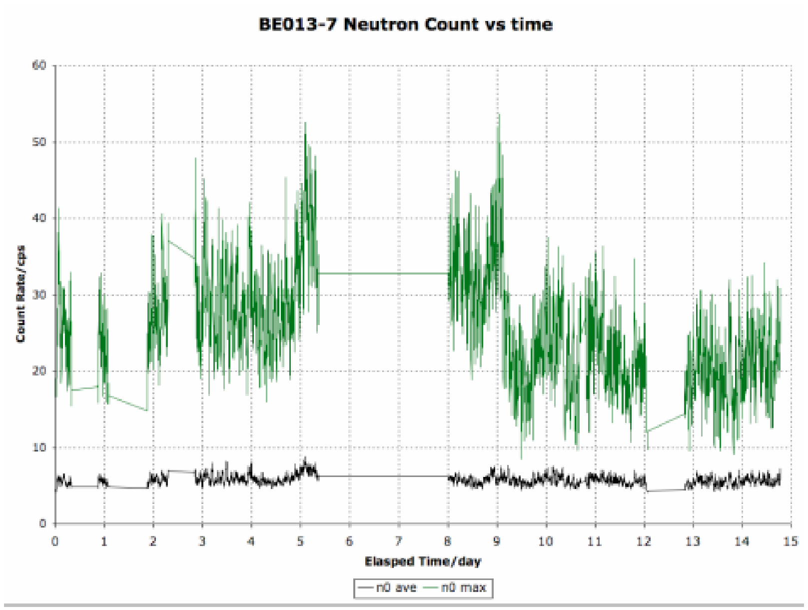
- only back side: N(fg) = 30.0±5.48 recoil protons/cm^2
- N(Bg) = 6 ±4 cm^{-2}
- ΔN = 24.0 ± 6.8 p/cm^2
- $\langle In \rangle = 2\langle \Delta N \rangle/(t \times \varepsilon s) = 48/(1.73 \times 10^6 x 9.2 \times 10^{-5}) = 0.30 \pm 0.08$ n/s in 2π solid angle

t = 14 hr etch

- back: N(Fg) = 45 cm-^{2}, front N(Fg) = 63 cm^{-2} $\langle N(fg) \rangle = 54.0 \pm 7.3$ cm^{-2}
- Background $\langle N(bg) \rangle = 26 \pm 5.1$ cm^{-2}
- ΔN = 28.0±8.9 cm^{-2}
- $\langle In \rangle = 2\langle \Delta N \rangle/(t \times \varepsilon_s) = 56/(1.73 \times 10^6 x 1.2 \times 10^{-4}) = 0.29 \pm 0.09$ n/s in 2π solid angle
- If t = 1 day In = 6.0±1.6 n/s in 2π solid angle

Neutron protocols for runs #5 and #7 in SRI





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Sensitivity to neutrons of SRI's BF_3 sphere and CR-39 neutron results

- Total fast neutron efficiency of the BF_3 detector (ε_t) is $7.6\text{x}10^{-5}$
  - Fast neutron self efficiency $\varepsilon_s = 7.6\text{x}10^{-3}$ (R~ 0 cm)
  - Distance between the detector and cathode wire is 10 cm
- Fast neutron sensitivity of the BF_3 detector $S = 3[\langle N_b\rangle/(\varepsilon_t^2\tau)\ ]^{1/2}$
  - Minimal neutron emission rate that can be distinguished from background
  - At least, 3 standard deviations from background
  - $\langle N_b \rangle$ = the average background count rate
  - τ = the duration of neutron detection.
- For Foreground #7: $\langle N_b \rangle \approx 6.0$ cps, τ = 15 days, => $S \approx 150$ n/s
  - 300 n/s, assuming neutron emission during only 4 days s
  - 100x higher than neutron emission forming CR-39 recoil protons
- For Foreground #5: τ = 20 days => $S \approx 130$ n/s
  - 400x higher than seen from CR-39
  - If τ = 1 day (length of peak seen in BF_3 detector) S ~ 600 n/s
  - ~ 100 times higher than seen in CR-39

Conclusions I

- Analysis of CR-39 detectors from two electrolysis experiments show that a weak, but statistically significant emission of fast neutrons has been observed .
- #7 detector, protected by 6 μm mylar film, shows “clean” front and back faces, containing only nuclear tracks (proton recoil).
- #5 detector, protected by 60 μm PE film, shows mixed zones of defects (“ground beef”) and nuclear tracks on its front side and lower (than #7) proton recoil density at the back side.
    - The small diameter defect pits can be eliminated by in-depth etching (removed depth h > 18 μm) allowing us to distinguish actual nuclear tracks of proton recoil, caused by neutrons as well as by energetic charged particles (protons and alphas) emitted from the PdD_x film deposited on the detector during electrolysis.
- Comparison of proton recoil spectra (track number vs. track diameter) of the Foreground, Blank, Background, and Cf-252 run detectors gives solid evidence for a fast neutron emission taking place during the runs #7 and #5.

Conclusions II

- Comparison of the neutron emission rates obtained from CR-39 analysis with SRI's proportional BF_3 detector measurements shows a large discrepancy.
  - The BF_3 detector results show orders of magnitude higher neutron emission than that calculated from the noiseless CR-39 data .
- Due to the low neutron sensitivity of the BF_3 detector (and absence of pulse-height/pulse shape analysis), we assume that the signal of BF_3 sphere contains significant electromagnetic noise.
- In order to provide additional confirmation of our CR-39 based neutron emission results, higher efficiency measurements with a more sophisticated electronic neutron detector would be desirable.

Acknowledgements

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