

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

A.G. Lipson¹, A.S. Roussetski^{2*}, F. Tanzella³,
E.I. Saunin¹, M. McKubre³

¹A.N. Frumkin Institute of Physical Chemistry and Electrochemistry,
Russian Academy of Sciences, Moscow 119991, Russia

²P.N. Lebedev Physics Institute, Russian Academy of Sciences,
Moscow 119991, Russia

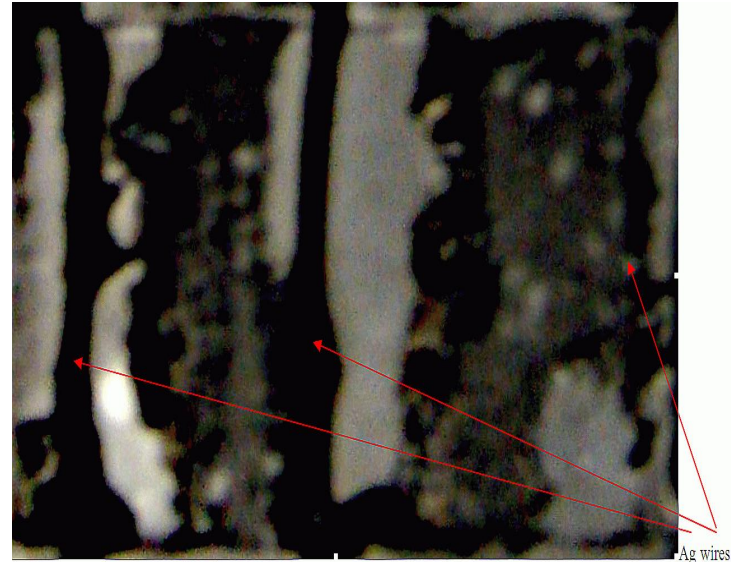
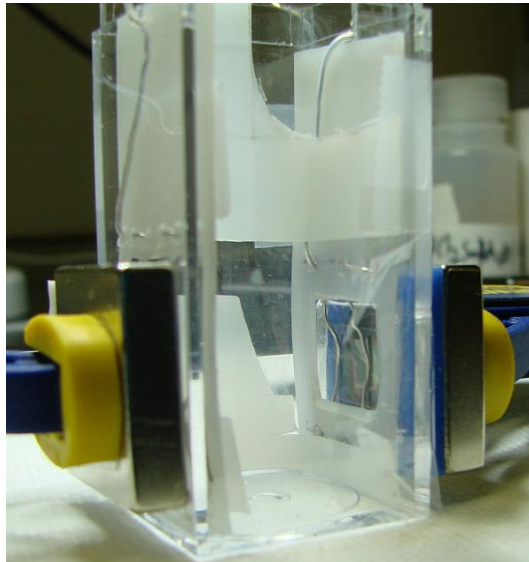
³SRI International, Menlo Park, CA, 94025, USA



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/cm² 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 (D₂O) to Blank (H₂O)
 - Compare Background (CR-39 2m from cell) to Foreground
 - Compare to BF₃ proportional detector count rate.

Electrolytic cell and detector placement



BE010-5 CR-39 and wires during electrolysis

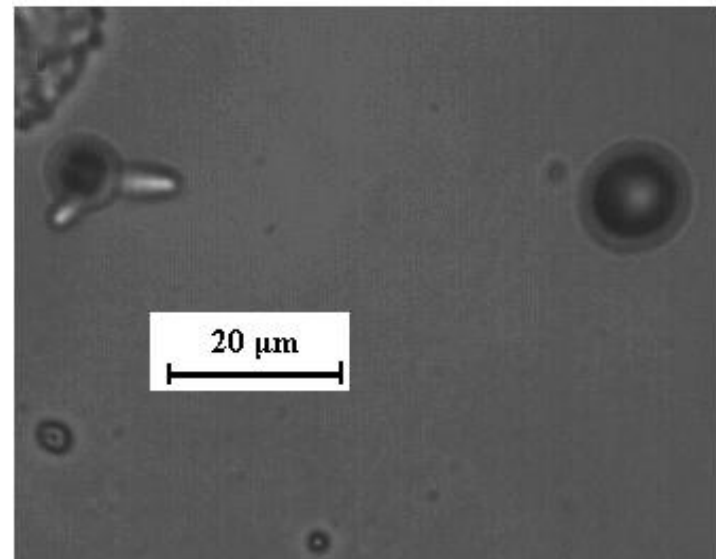
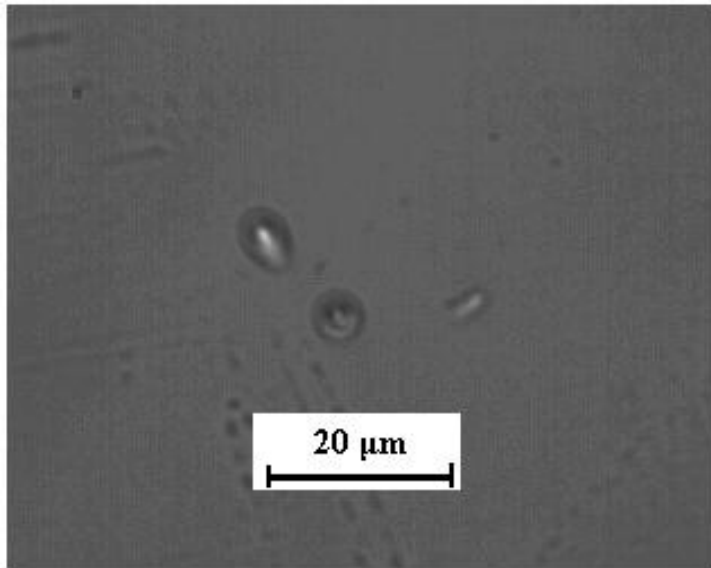
- Cr-39 detector in runs #7 and #5 were separated from the cathode and electrolyte by sheets of 6 μm Mylar® and 60 μm polyethylene, respectively.
- BF_3 spherical neutron dosimeter with low self-efficiency $\epsilon_s = 2.5 \times 10^{-3}$ (Cf-252)
 - Statistically significant (neutron?) counts were detected at SRI during the runs



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 ($v_b \approx 1.3 \mu\text{m/hr}$).
- 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 ($I_n = 120 \text{ n/s}$)
- 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

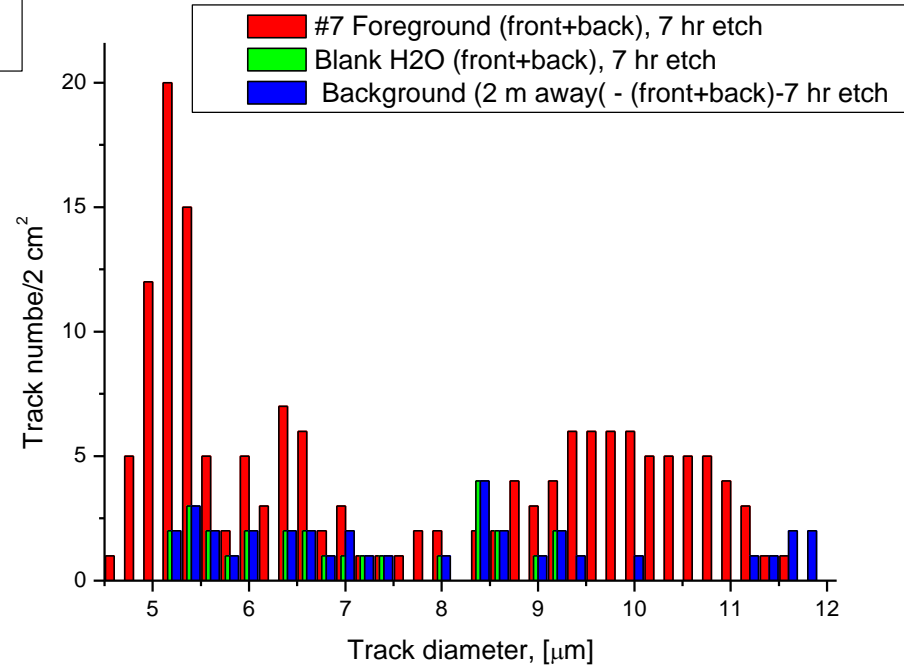
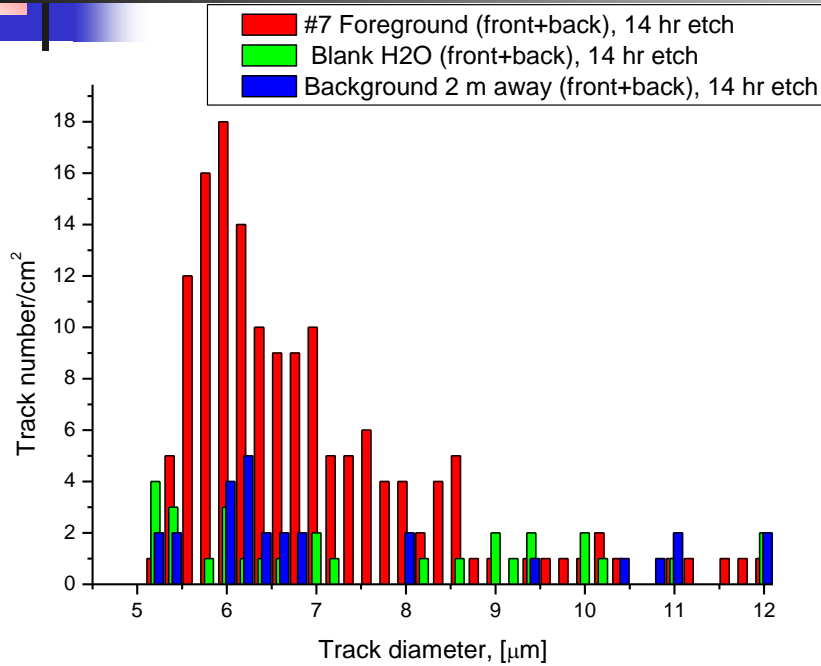




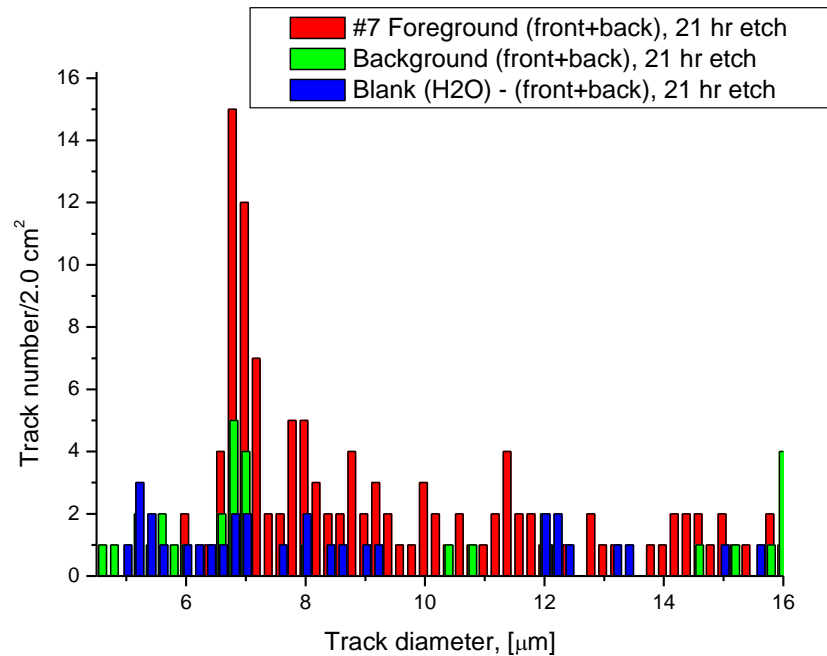
Neutron calibration results

- Proton recoil spectrum after 7 hr etch is at 4.5-9.0 μm track diameter (maximum at 5.2 μm)
 - 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 5.0-12.0 μm track diameter (maximum at 6.0 μm)
 - 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 ($\epsilon_n \sim 1.2 \times 10^{-4}$) is about factor of 1.3 higher than that at $t = 7$ hr ($\epsilon_n \sim 0.9 \times 10^{-4}$) due to increase in proton recoil critical angles with the removed CR-39 depth.
- Raw data available in Catania Workshop Proceedings, p182

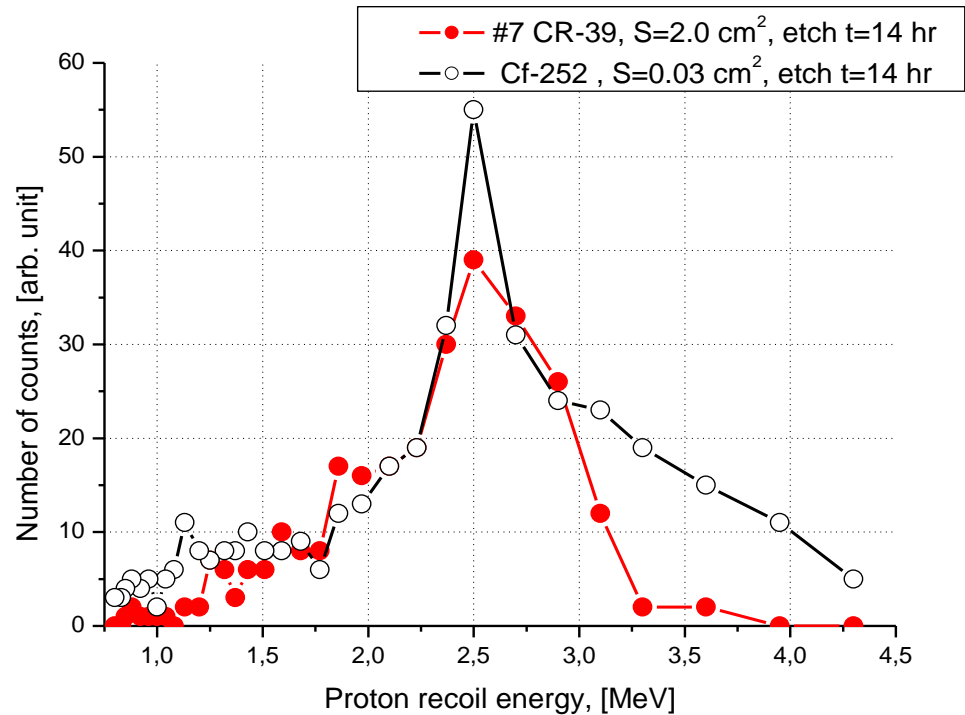
Comparison of Foreground #7 data (both sides) with CR-39 (H₂O electrolysis), Background after 7 and 14 hr etches. Blank and the Background show no sign of proton recoil from fast neutrons (no irradiation on shipping).



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



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





Calculation of mean neutron emission rate:

I. For 7 hr etch time removed depth is 8.7 μ m

- Average foreground track density ($\langle N(\text{fg}) \rangle$) is 58.5 cm⁻².
- Average background track density ($\langle N(\text{bg}) \rangle$) is 6.0 cm⁻².
 - Both sides of Blank detector
- $\langle \Delta N \rangle = \langle N(\text{fg}) \rangle - \langle N(\text{bg}) \rangle = 52.5 \pm 8.0$ track/cm².
- Neutron count rate/intensity from cathode wire (I_n) is $2\langle \Delta N \rangle / (t \times \epsilon_s)$
 - $\epsilon_s = 9.2 \times 10^{-5}$ (CR-39 self-efficiency at $t_{\text{etch}} = 7$ 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 \pm 0.14 n/s
- If the neutrons were emitted when the only when the BF₃ counter read high ($\Delta t = 4$ days) $I_n =$ **3.38 \pm 0.53 n/s** |
- 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)

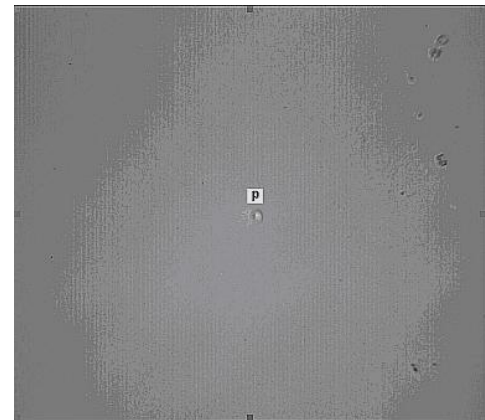
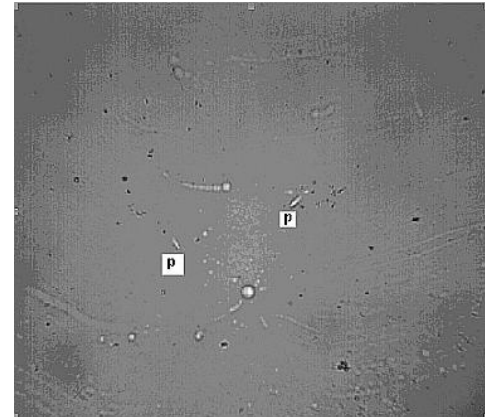
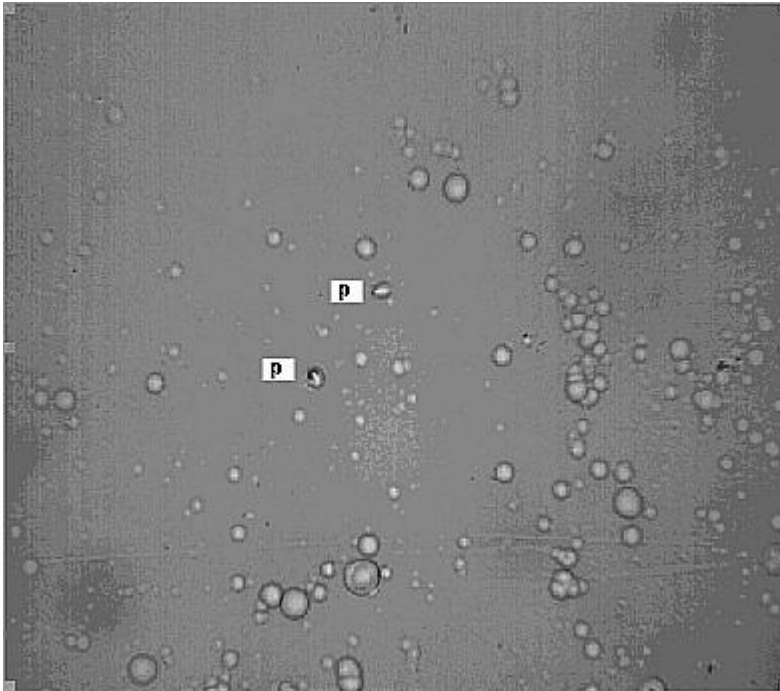
- Average track density at both sides of #7 CR-39 is $\langle N(\text{fg}) \rangle = 88 \text{ cm}^{-2}$.
- The Background track density at both sides of blank detector ($S = 0.25 \text{ cm}^2$ each) is the $\langle N(\text{bg}) \rangle = 26 \text{ cm}^{-2}$.
- Accordingly to calibration measurements CR-39 at etch time $t_{\text{et}} = 14 \text{ hr}$ the self-efficiency was found to be $\varepsilon_s = 1.17 \times 10^{-4}$.
- Then, for $t = 15 \text{ days}$: $I_n = 2\langle \Delta N \rangle / (t \times \varepsilon_s) = \mathbf{0.82 \pm 0.14 \text{ n/s}}$ in 2π solid angle and for $\Delta t = 4 \text{ days}$ $I_n = \mathbf{3.08 \pm 0.53 \text{ n/s}}$. 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).

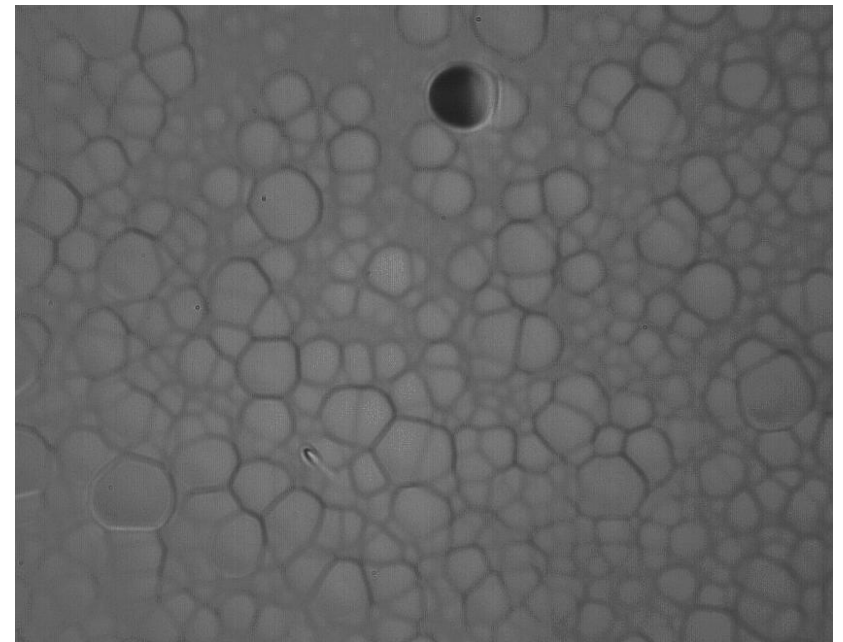
Proton recoil tracks on the front side of the #5 detector
easily differentiated from the defect (“ground beef”)
Background at $t = 14$ hr etch



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



$2\alpha + 1p$



$1\alpha + 1p$

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

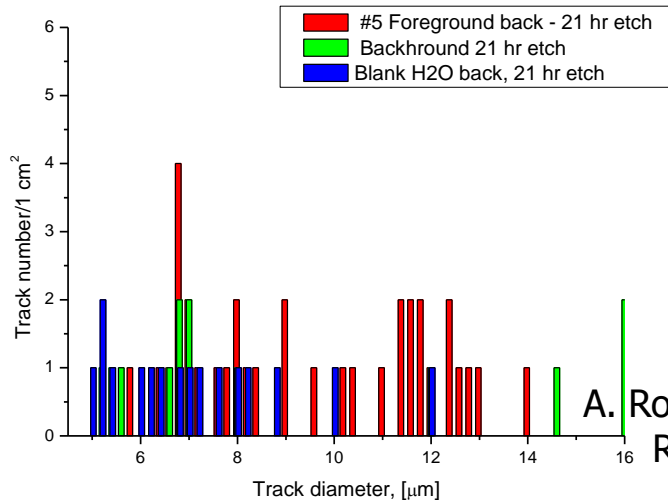
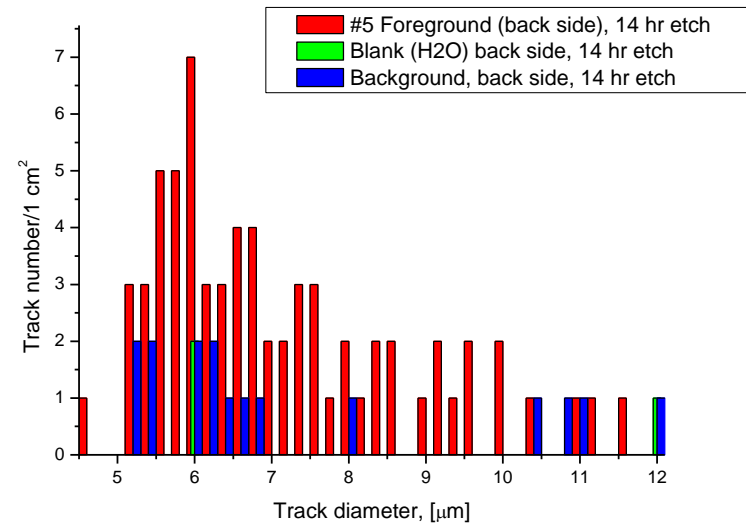
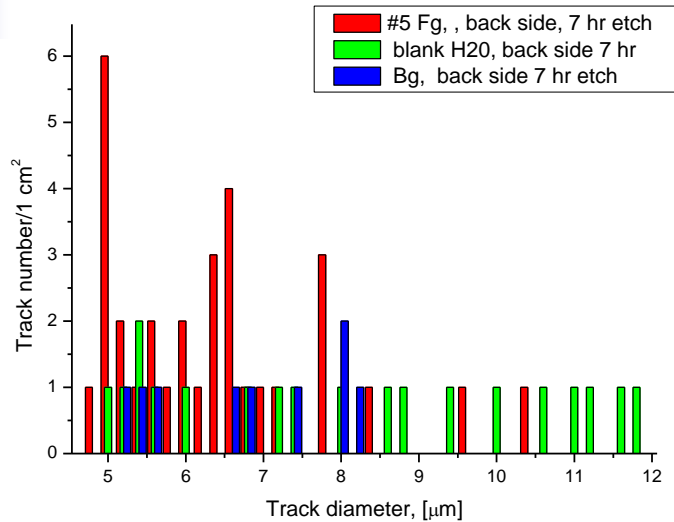


single oblique recoil protons



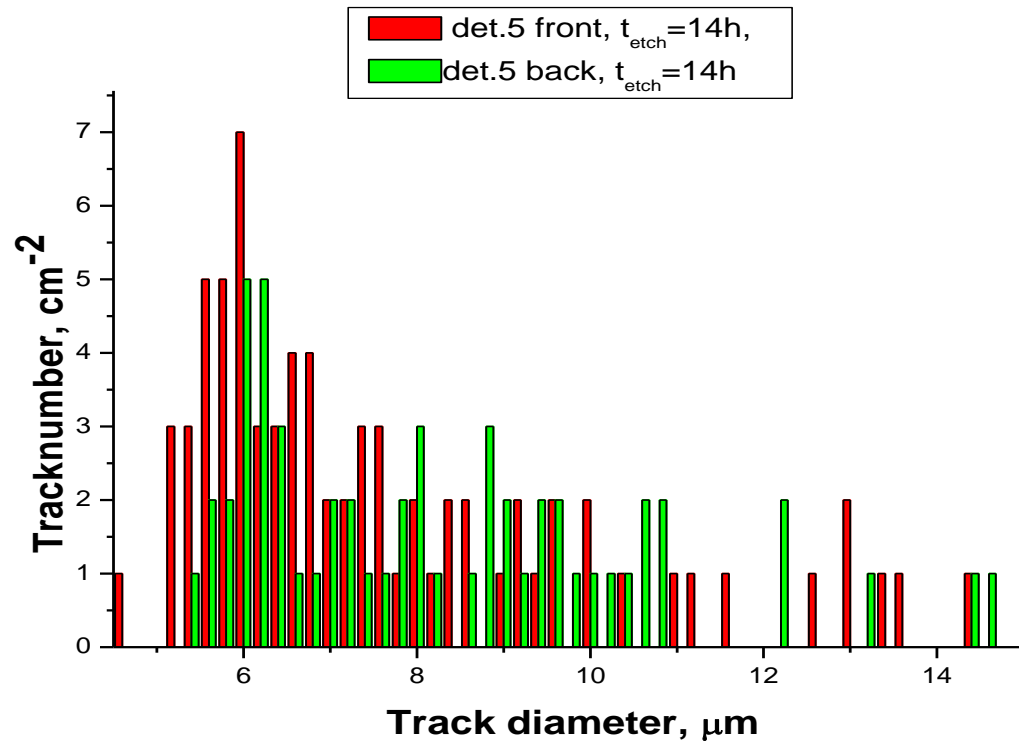
normal incidence recoil protons

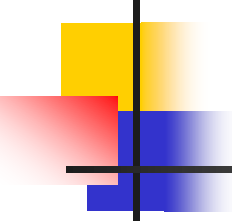
Proton recoil tracks from the “clean” back side of #5 detector after 7, 14, and 21 hr etches



A. Roussetski et al, ICCF-15,
Rome, 10/5-9, 2009

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





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

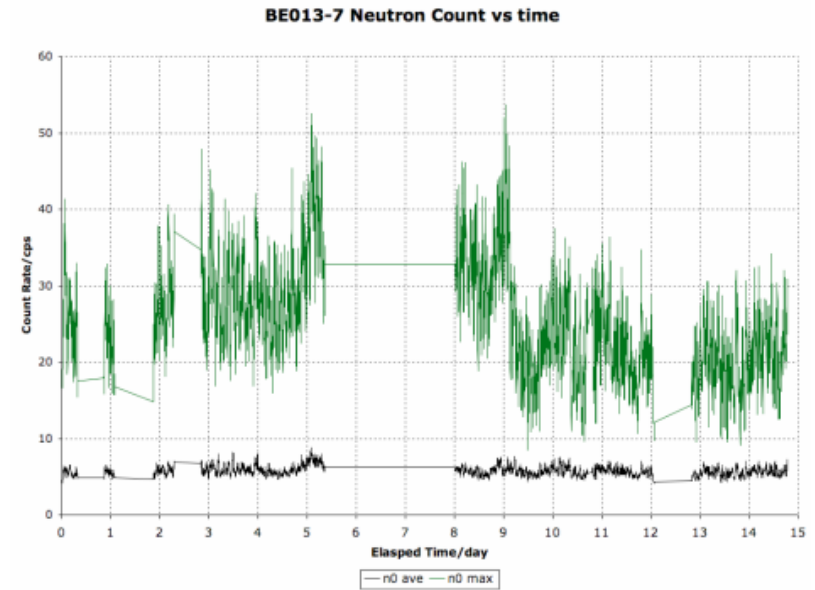
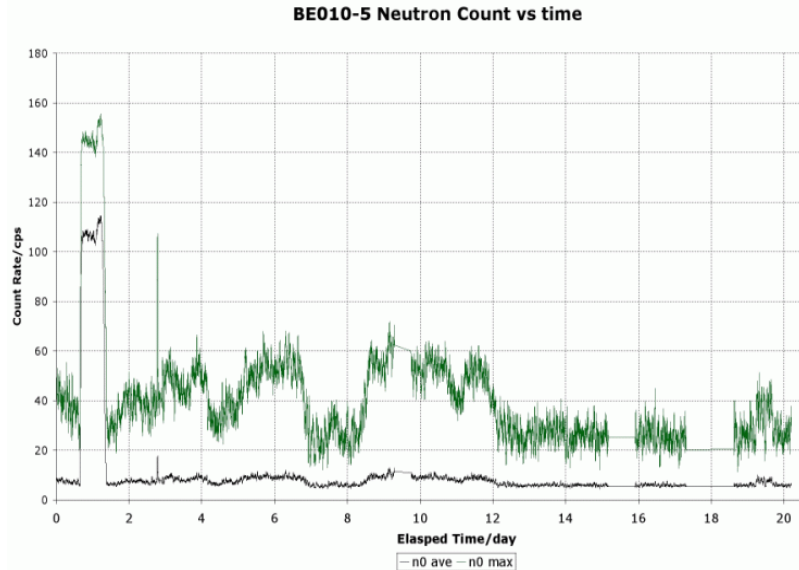
$t \sim 7$ hr etch

- only back side: $N(\text{fg}) = 30.0 \pm 5.48$ recoil protons/cm²
- $N(\text{Bg}) = 6 \pm 4$ cm⁻²
- $\Delta N = 24.0 \pm 6.8$ p/cm²
- $\langle I_n \rangle = 2\langle \Delta N \rangle / (t \times \epsilon_s) = 48 / (1.73 \times 10^6 \times 9.2 \times 10^{-5}) = 0.30 \pm 0.08$ n/s in 2π solid angle

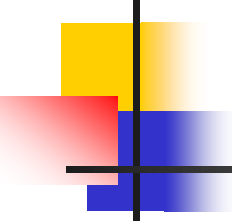
$t = 14$ hr etch

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

Neutron protocols for runs #5 and #7 in SRI



A. Roussetski et al, ICCF-15,
Rome, 10/5-9, 2009



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 7.6×10^{-5}
 - Fast neutron self efficiency $\epsilon_s = 7.6 \times 10^{-3}$ ($R \sim 0$ cm)
 - Distance between the detector and cathode wire is 10 cm
- Fast neutron sensitivity of the BF_3 detector $S = 3[\langle N_b \rangle / (\epsilon_t^2 \tau)]^{1/2}$
 - 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, $\tau = 15$ days, $\Rightarrow S \approx 150$ 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: $\tau = 20$ days $\Rightarrow S \approx 130$ n/s
 - 400x higher than seen from CR-39
 - If $\tau = 1$ day (length of peak seen in BF_3 detector) $S \sim 600$ 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 $h > 18 \mu\text{m}$) 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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