# Time Resolved, High Resolution, γ–Ray and Integrated Charged and Knock-on Particle Measurements of Pd:D Co-deposition Cells

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**L.P.G. Forsley[1], P.A. Mosier-Boss[3], G.W. Phillips[1], S. Szpak[3], J.W. Khim[2], and F.E. Gordon[3]**

[1]*JWK Technologies Corporation, Annandale, VA 22003 (lforsley@jwk.com)*
[2]*JWK Corporation, Annandale, VA 22003*
[3]*US Navy SPAWAR Systems Center, San Diego, CA 92152*

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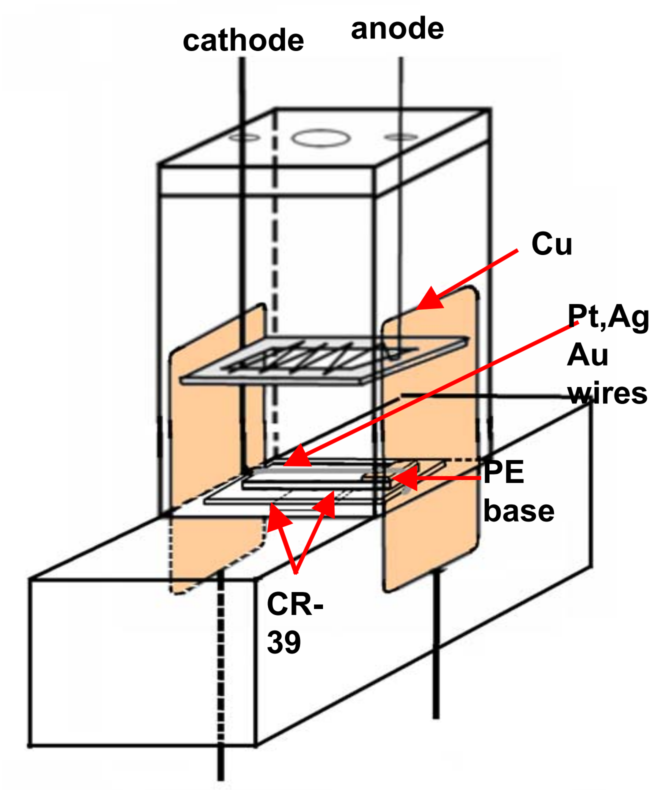
r6

# E field 3 wire, (Pt, Ag, Au) Experiments

## SPAWAR
## Co-Deposition Cell




## Diagnostics

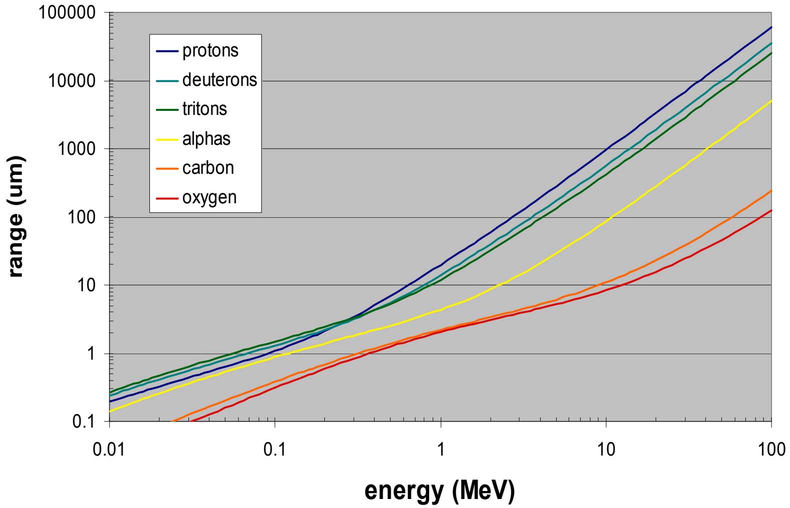
**CR-39: solid state detector, Polyallyl diglycol carbonate (PADC) integrates charged particles and neutrons. Read with TASL scanner. Each 10 mm x 20 mm chip handled as 1000, 500 μm x 600 μm images**

**HPGe[1]: cryogenically cooled γ detector, 50 keV - 2.5 MeV range 2 keV resolution @1.3 MeV, 13 sec time intervals.**

[1]HELGA-2, developed by NRL and JWK.

# Charged Particles in CR-39

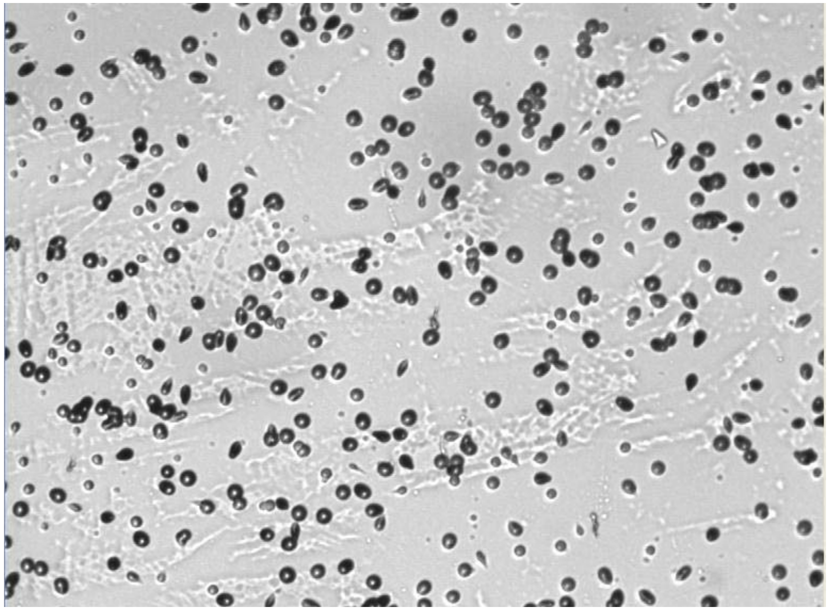
## Charged particle range




**1 mm CR-39 will stop:**

**10 MeV $p^+$**
**14 MeV $^2H$**
**40 MeV $\alpha$**

## $^{238}U$ $\alpha$ tracks



← 600 μm →

**Etched 6 hours**
**6.5 M NaOH, 70° C**

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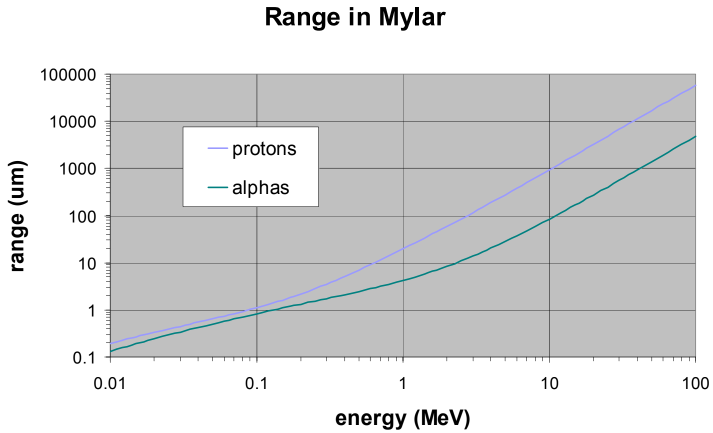
# Co-deposition Behind 6 μm Mylar Window

## Range through Mylar



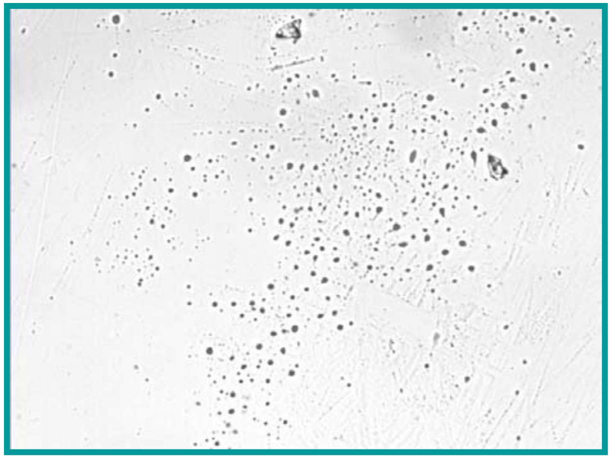

3 wire E-field "dry" experiment with no contact between CR-39 and electrolyte.

**Through 6 μm Mylar particles will lose:**

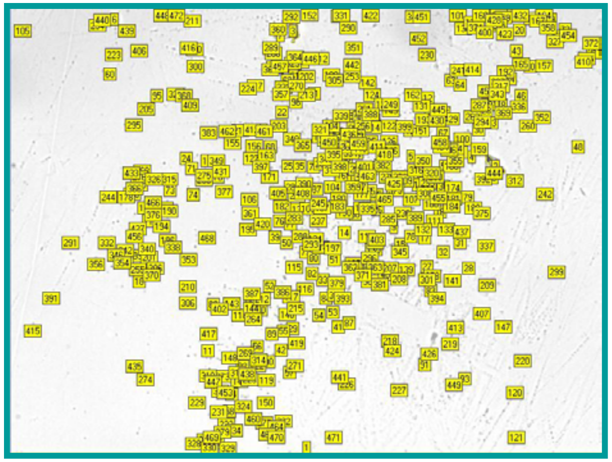
**$p^+$ 0.45 MeV**

**$\alpha$ 1.40 MeV**

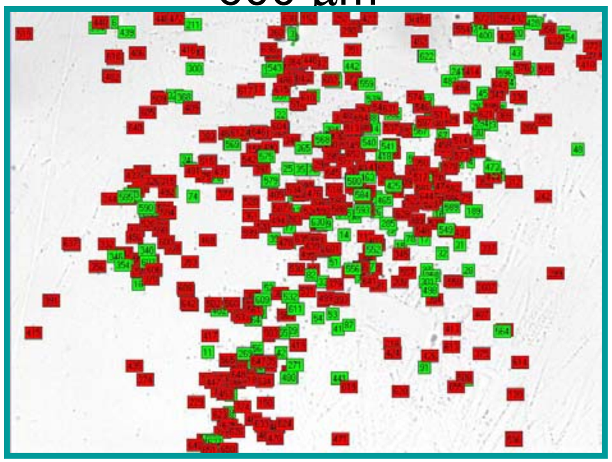
← 600 μm →



image



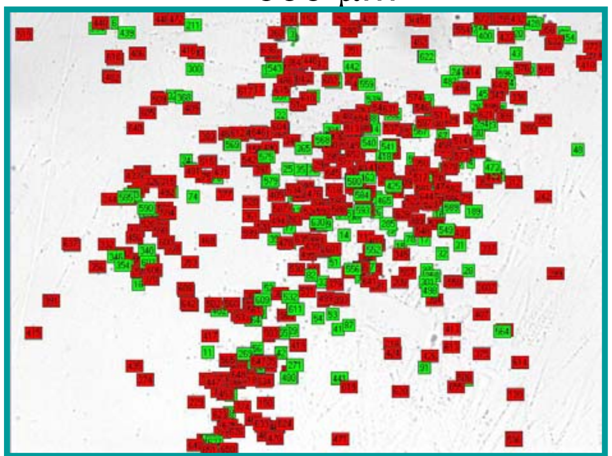
processed

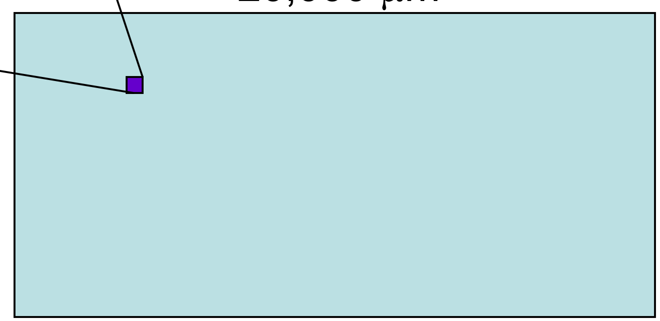


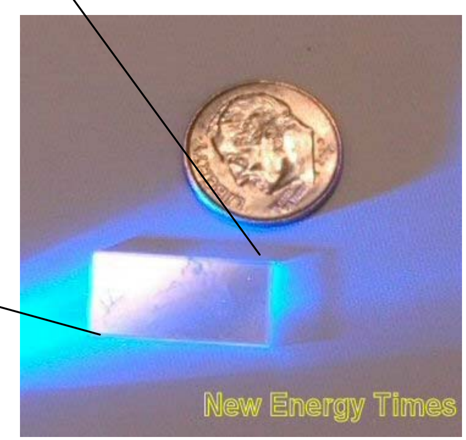
identified

# Mylar Window Experiment - Scale View

(Supplemental Slide)

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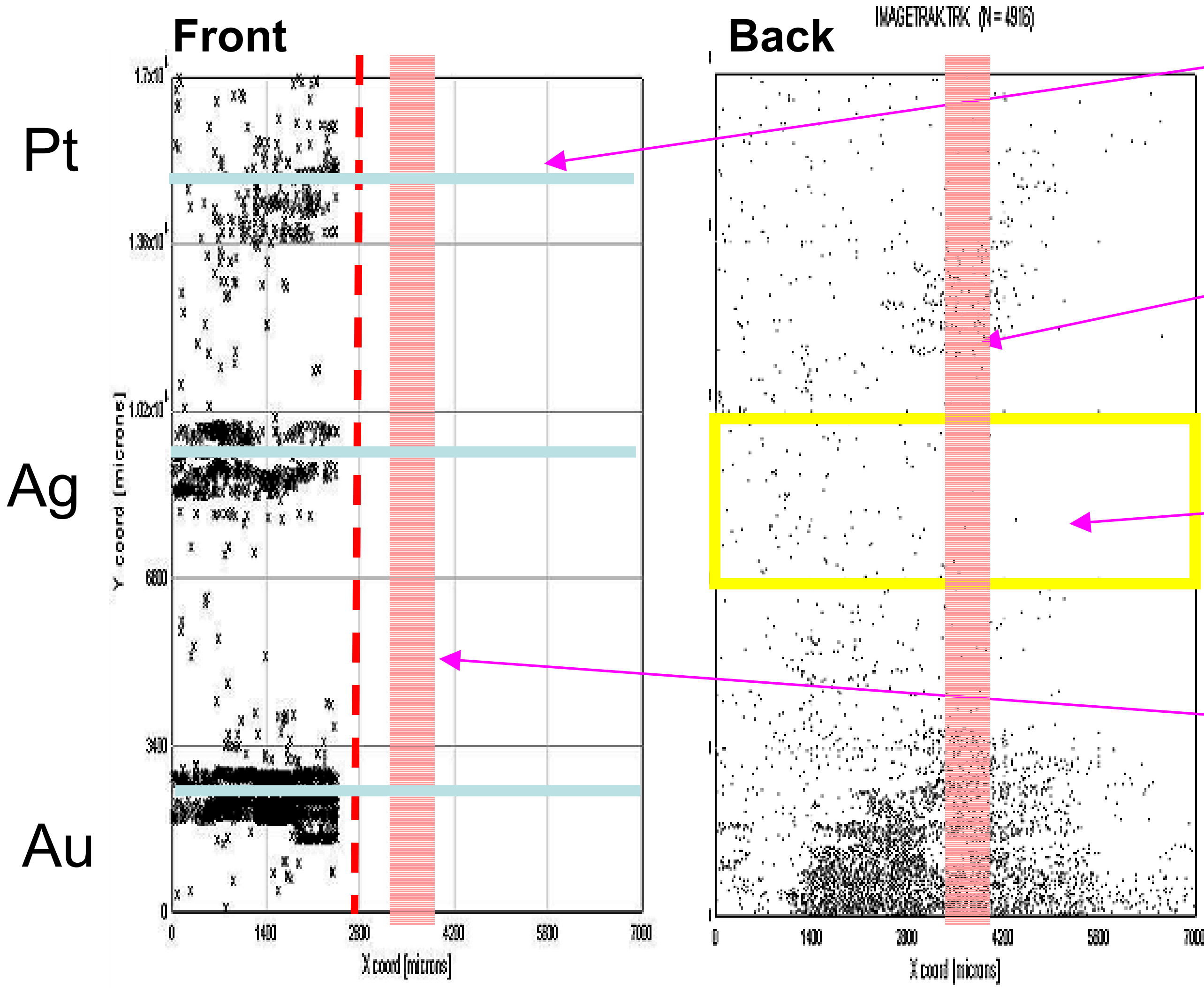
# Surface Comparison (Supplemental Slide)

***Particle track locations for 3 wire E-field "wet".***




Approx location and scale of three wires

Two sections are shown in detail in next slide

Area selected for calibration

Data is present here, but it was only seen when scanned separately because of the oversaturation problem

The dotted red line shows where the track density saturated the scanner and halted the scanning process.

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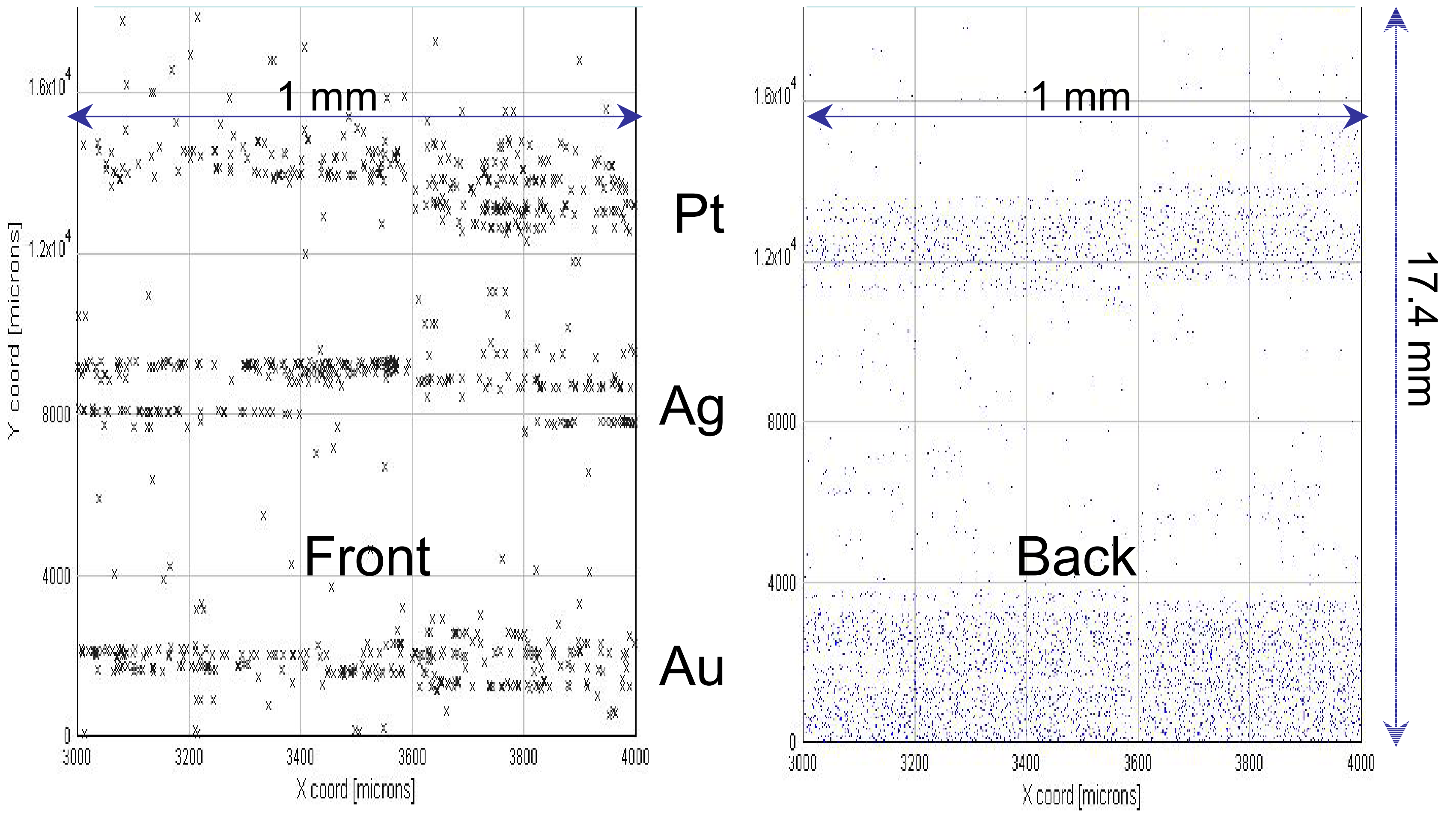
# Scan 1 mm by 17.4 mm



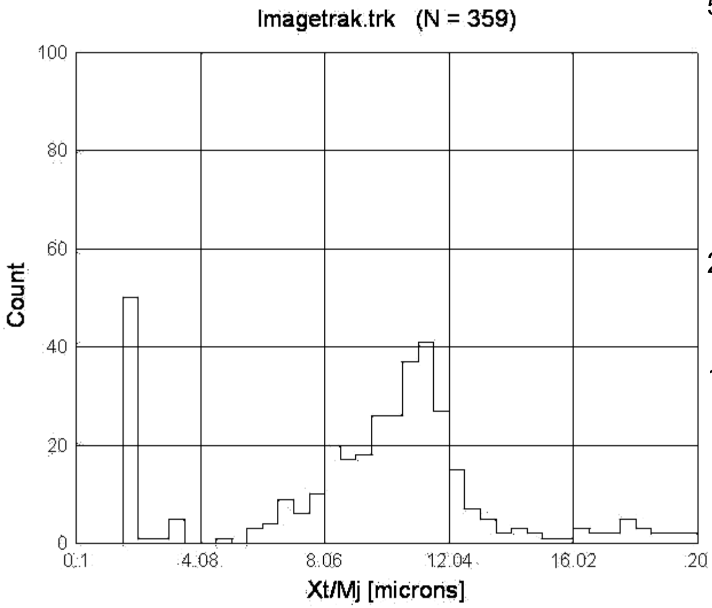

Pt, Ag, Au tracks on front. Pt and Au tracks on back.

***No tracks from Ag on back!***

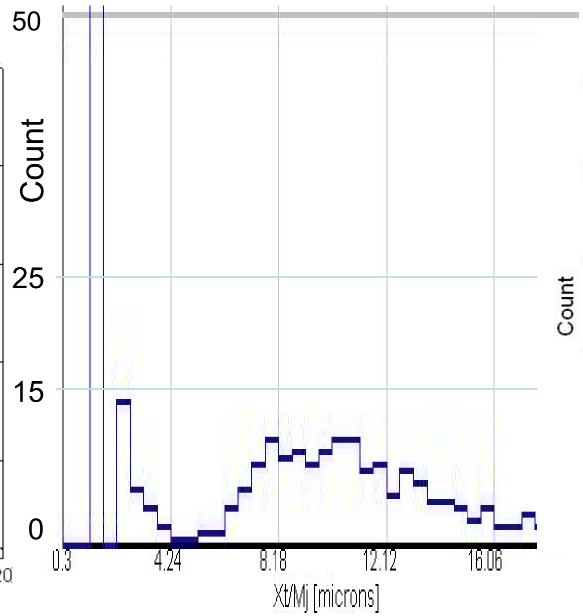
# Counts vs Major Axis

***The particles', or knock-ons', track size distribution.***

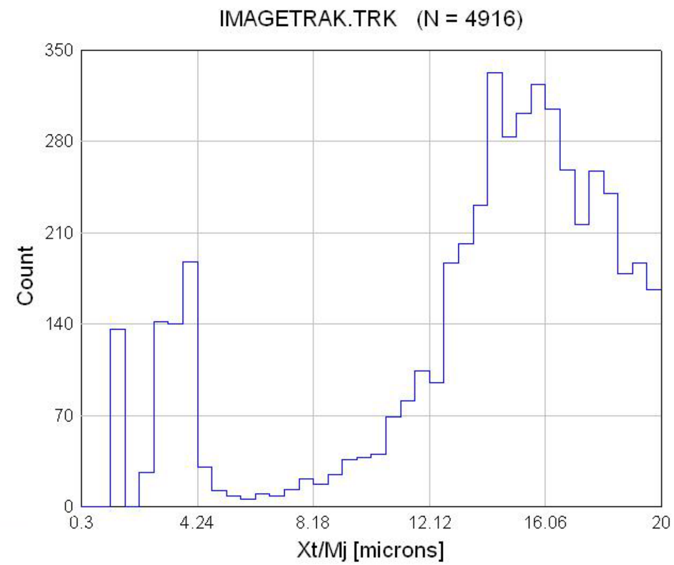
$^{238}U$ calibration




E field, wet, 3 wire, front




E field, wet, 3 wire back




All show tri-modal maximum diameter distributions, $d_n$.

$^{238}U$: $d_1$, 2.0 μm; $d_2$, 3.5 μm; $d_3$, 8 - 12 μm, 4.2 MeV α

Front: $d_1$, 1.5 μm; $d_2$, 3.5 μm; $d_3$, 6 - 14 μm > 4.2 MeV α?

Back: $d_1$, 1.7 μm; $d_2$, 3.8 μm; $d_3$,12 - 20+ μm > 40 MeV α? (1 mm CR-39!)

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***Something is causing large tracks on the back!***

JWK

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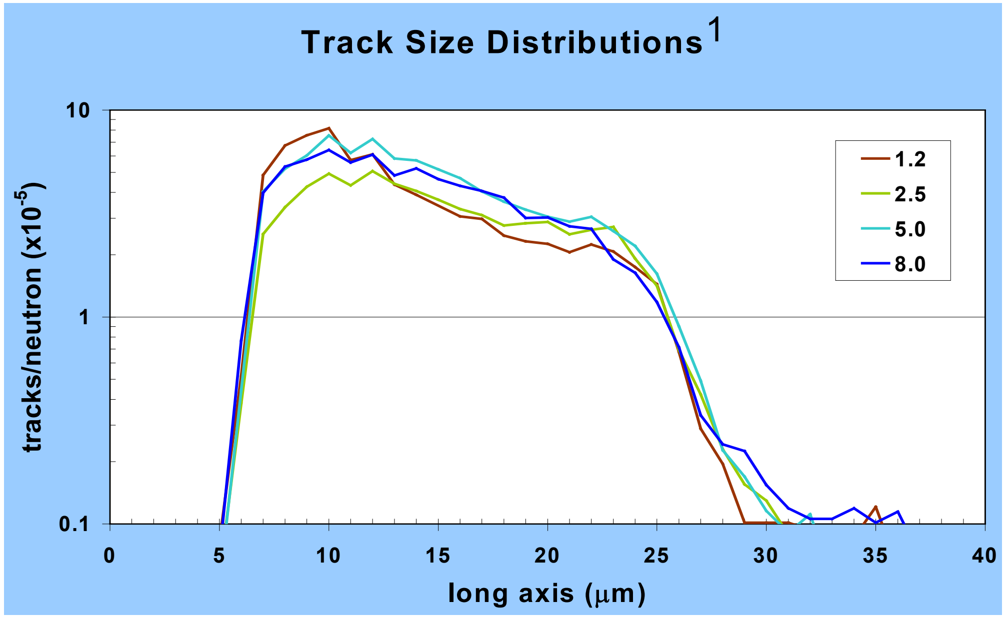
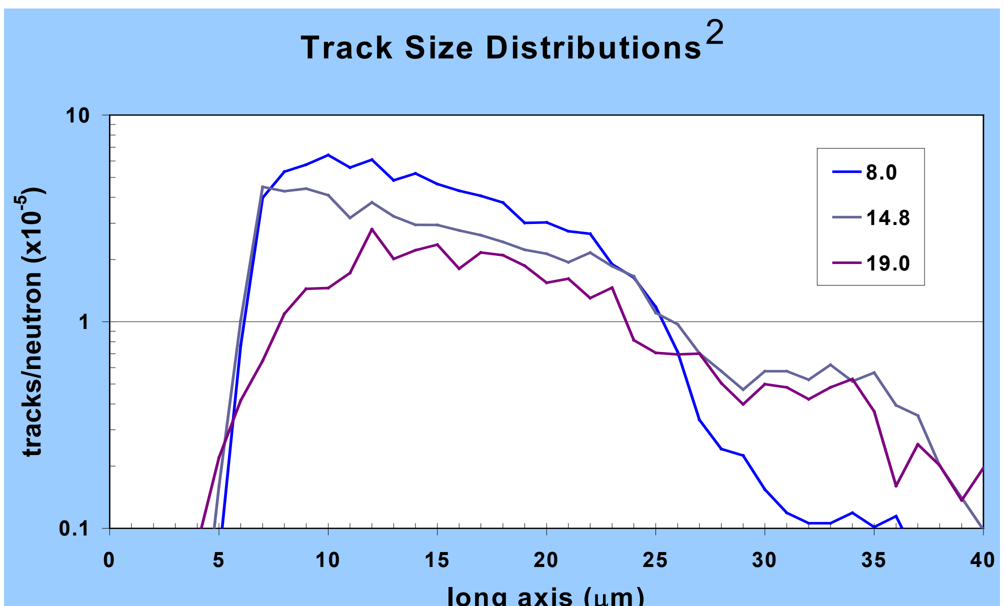
# Neutron Track Size




**CR-39 n efficiency $10^{-4}$ - $10^{-6}$ tracks/n**

**n tracks caused by knock-on with CR-39 ($C_{12}H_{18}O_7$) atoms:**

**$^{1}H$, $^{12}C$, $^{16}O$**

**$n_e$ > 12 MeV will break $^{12}C$ into $\alpha$ particles, leaving a "triple" track.**

**These $\alpha$ particles will have little momentum and won't move.**

**Uniform number of knock-ons throughout CR-39 thickness due to low neutron stopping power.**

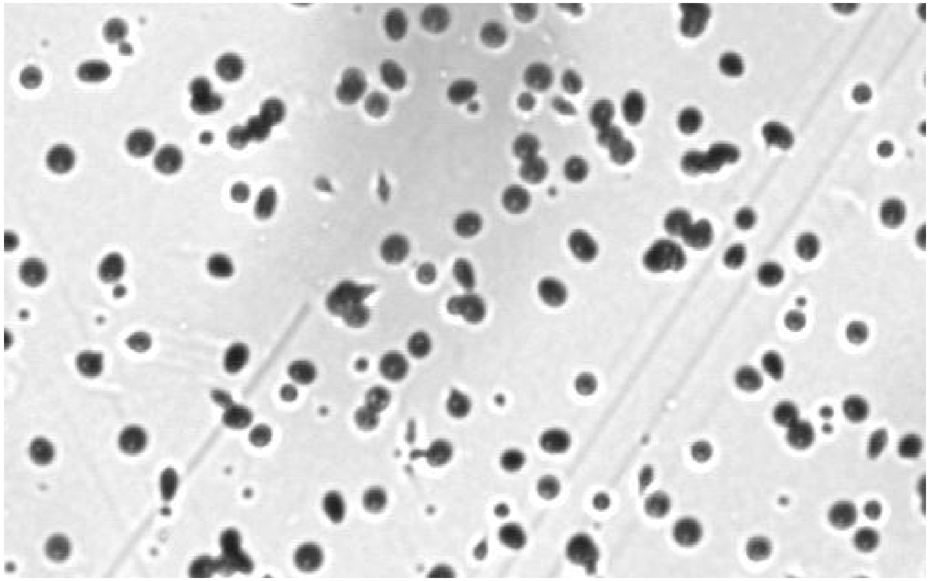
**Track size function of n energy, $n_e$.**

**Adjacent plots show $n_e$ range from 1.2 MeV to 19 MeV.**

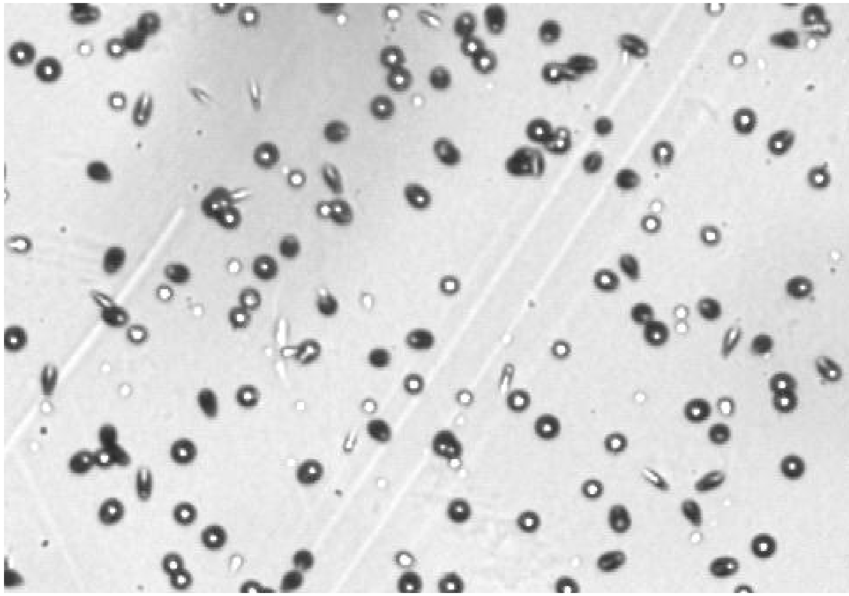
[1,2] Phillips, *et. al.*, "Neutron Spectrometry Using CR-39 Track Etch Detectors", *14th SSD,* 2004.

# Neutrons?

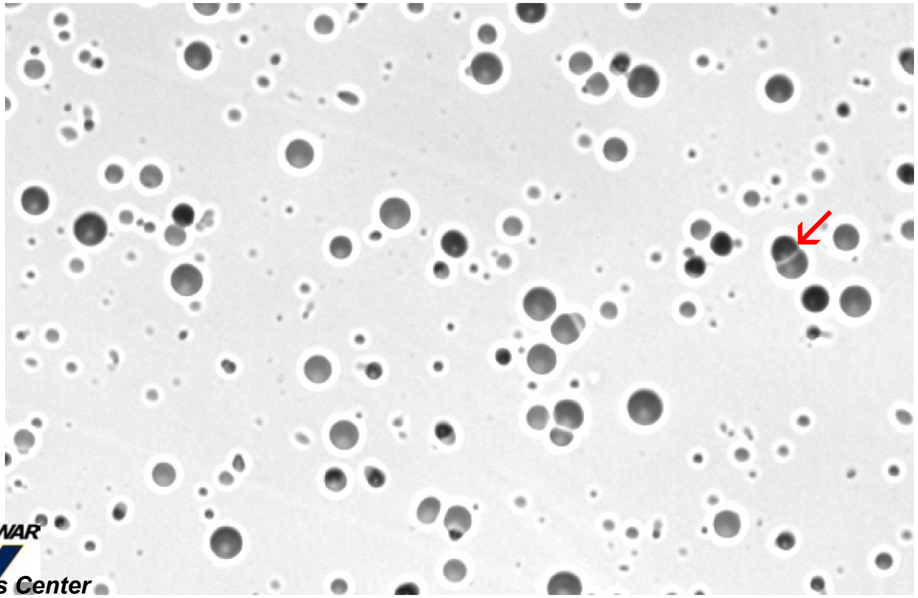
3 Wire E field, back side



Back side, deeper focus



$^{238}$PuO fission neutron source of knock-ons[1]



**Note different size tracks and bright center at deeper focus.**

**If neutrons, further etching will expose new tracks, as shallower tracks disappear.**

**Note double tracks.**

[1] Phillips, *et. al*., "Neutron Spectrometry Using CR-39 Track Etch Detectors", *14th SSD,* 2004.

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# Preliminary Gamma Ray Data

Data from Pd:D co-deposition on Ni screen taken over 10 hour period.
Unexpected $\gamma$ lines, possibly co-incident, not present in background spectrum, occurred in multiple, consecutive, 13 second time windows:

**$^{92}Sr_{38}$** $t_{1/2}$ = 2.7 hr, $\beta^-$ and $\gamma$ decay
1.3839 MeV $\gamma$ 1.062 x $10^{-2}$ activity (relative units)[1]

**$^{97}Zr_{40}$** $t_{1/2}$ = 16.9 hr, $\beta^-$ and $\gamma$ decay
743.36 keV $\gamma$ 9.615 x $10^{-4}$ activity (relative units)[2]

Ratio of $Zr_{t_{1/2}}/Sr_{t_{1/2}}$ = 6.3
Ratio of $Sr_{act}/Zr_{act}$ = 11.1

The 6x shorter half life isotope is 11x brighter!

**Gamma-ray emissions and activity ratio consistent with $^{92}Sr_{38}$ and $^{97}Zr_{40}$ decays.**

[1] Missing lines at 241.52, 130.56, 953.32, 1142.30 keV: primary line present, $I_\gamma$ =90%.
[2] Missing lines at 254.15, 355.39, 507.63, 602.52, …. keV: primary line present, $I_\gamma$ =93%.

***These values were integrated during a single 13 second time window.***

# Conclusions

1. The SPAWAR co-deposition cell consistently, and repeatedly, produces tracks.
2. Tracks are consistent with both nuclear charged particle and neutron knock-on tracks.
3. Tracks are not of chemical origin, although chemical damage may occur.
4. $\gamma$ data offers insight into nuclear mechanisms causing tracks.
5. More real-time, spectrally resolved, charged particle, neutron and $\gamma$ diagnostics needed.
6. Robust SPAWAR protocol may allow theory determination.