

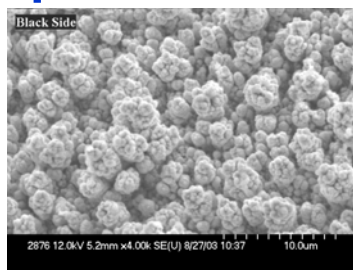
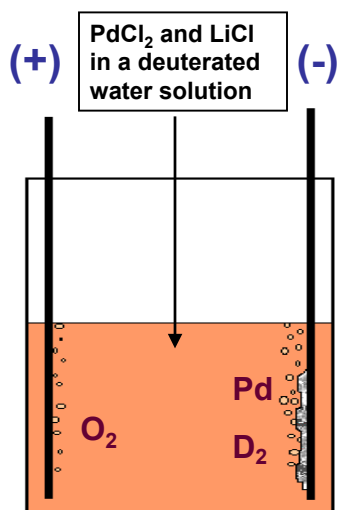
# Pd/D Co-Deposition: Excess Power Generation and Its Origin

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233<sup>rd</sup> ACS National Meeting and Exposition  
Symposium on New Energy Technology  
Chicago, IL  
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## Pd/D Co-Deposition

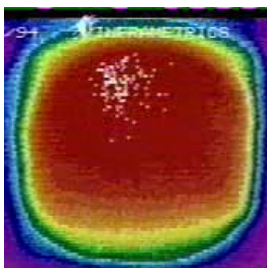
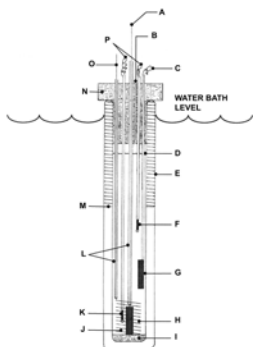


As current is applied, Pd is deposited on the cathode. Electrochemical reactions occurring at the cathode:



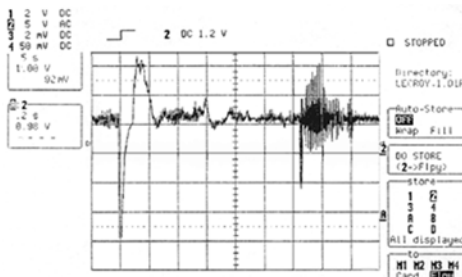
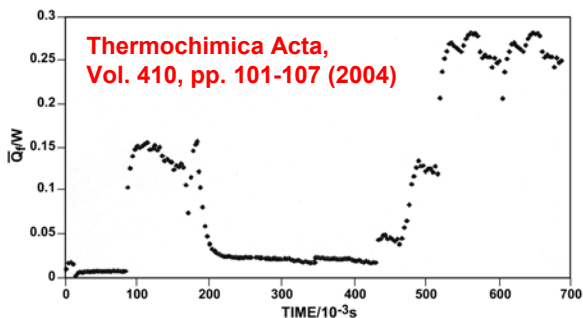
The result is metallic Pd is deposited in the presence of evolving D<sub>2</sub>

# Excess Enthalpy

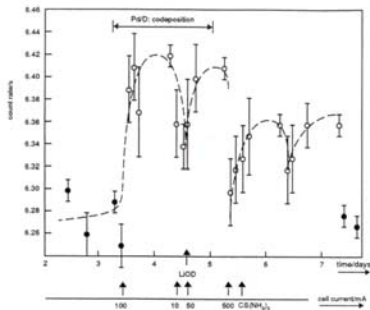
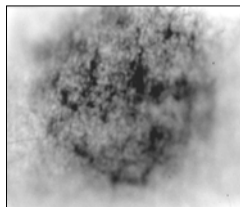


**Il Nuovo Cimento,**  
Vol 112A, pp. 577-585 (1999)

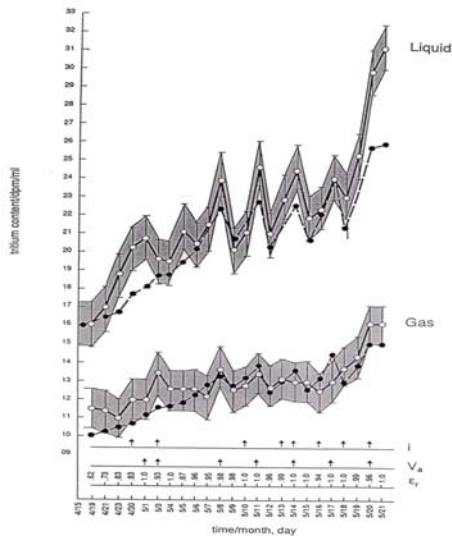
**Thermochimica Acta,**  
Vol. 410, pp. 101-107 (2004)



# Search for Nuclear Ash

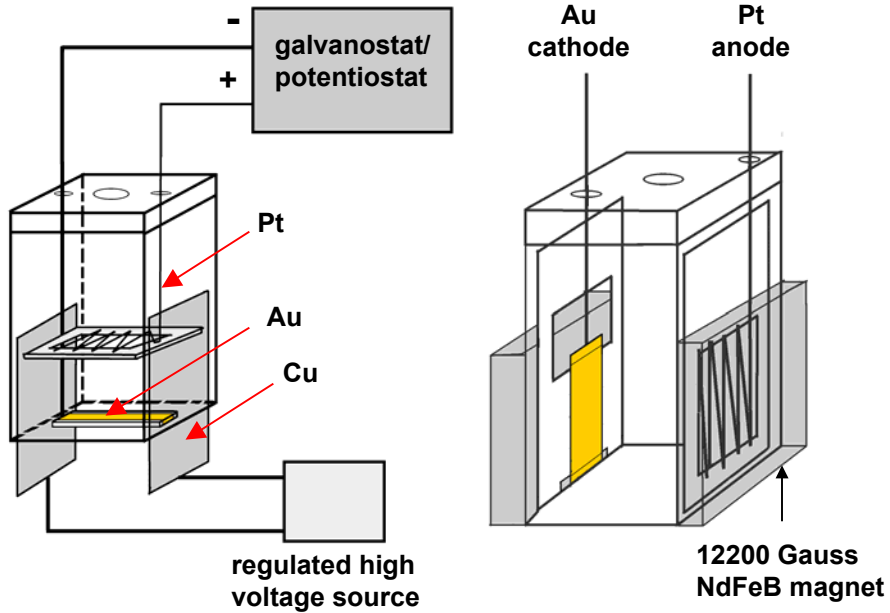


**Radiation emission**  
**Physics Letters A, Vol. 210, pp. 382-390 (1996)**

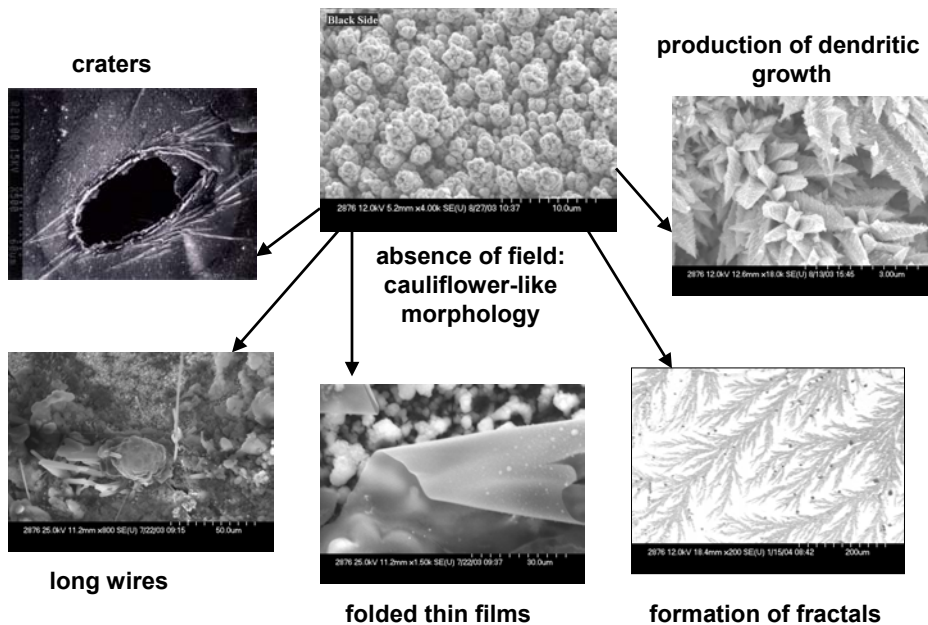


**Tritium production**  
**Fusion Technology, Vol. 33, pp.38-51 (1998)**

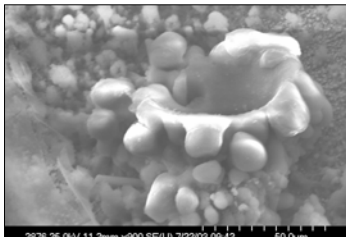
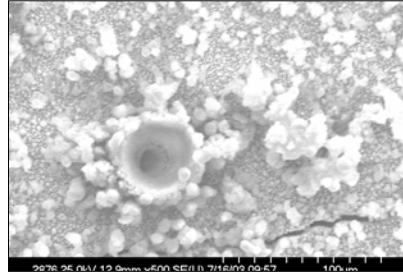
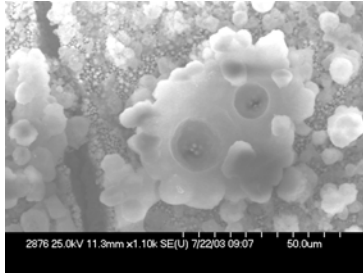
## External Electric and/or Magnetic Field Experimental Configuration



## E-Field Morphology Changes

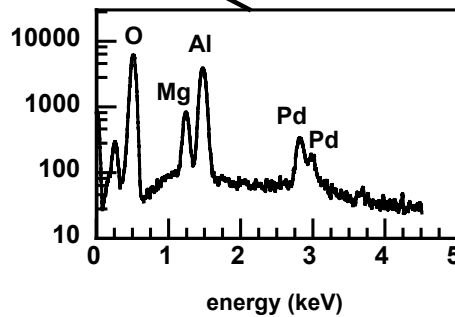
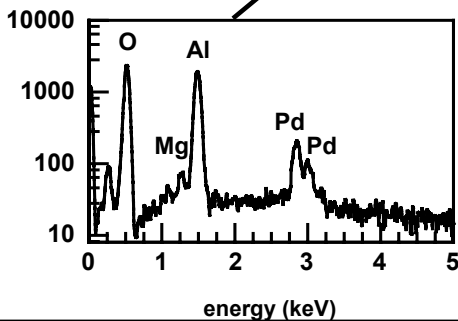
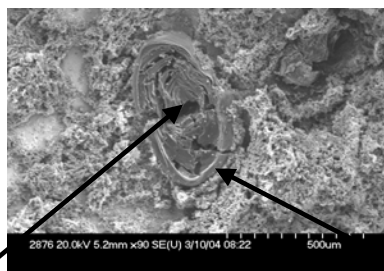


## E-Field: Micro-Volcano-Like Features

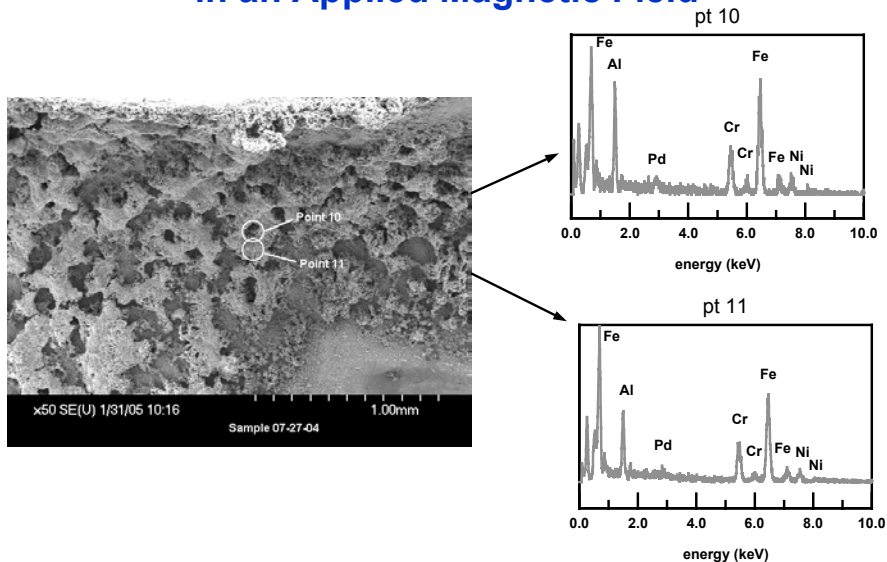


- Features suggestive of solidification of molten metal.
- Energy needed to melt metal is of a nuclear origin.
  - Should be reflected by chemical analysis of these features

## E-field: Chemical Composition of the Inside and Outside Rims of a Crater



## Chemical Composition of Structures Formed in an Applied Magnetic Field



## How Can We Verify that the Observed New Elements are Nuclear in Origin?

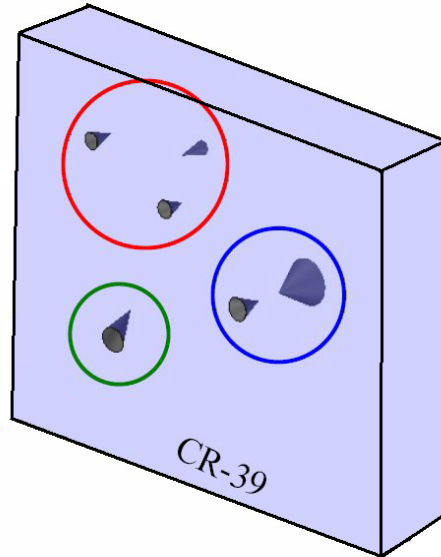
- **SEM-SIMS: look for changes in the isotopic ratios**
- **Measure  $\gamma$  and X-ray emissions**
- **Detect particle emission using CR-39 chips**
  - Easy to do
  - Inexpensive
  - Requires minimal instrumentation
  - Is a 'constant integration' method
  - No electronics

## Particle Detection Using CR-39

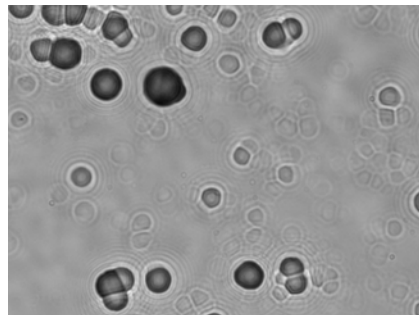
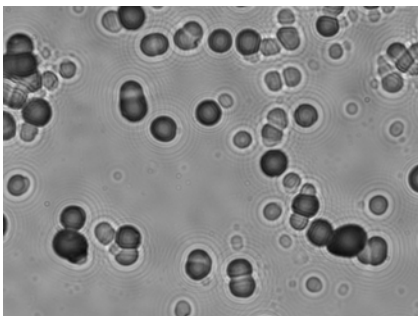
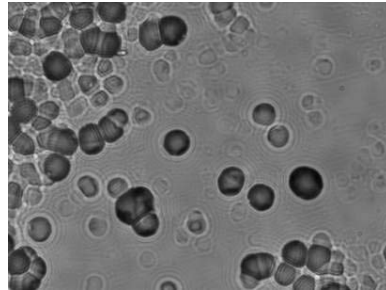
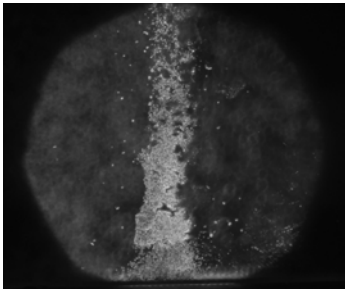
- CR-39, polyallyldiglycol carbonate polymer, is widely used as a solid state nuclear track detector

- When traversing a plastic material, charged particles create along their ionization track a region that is more sensitive to chemical etching than the rest of the bulk

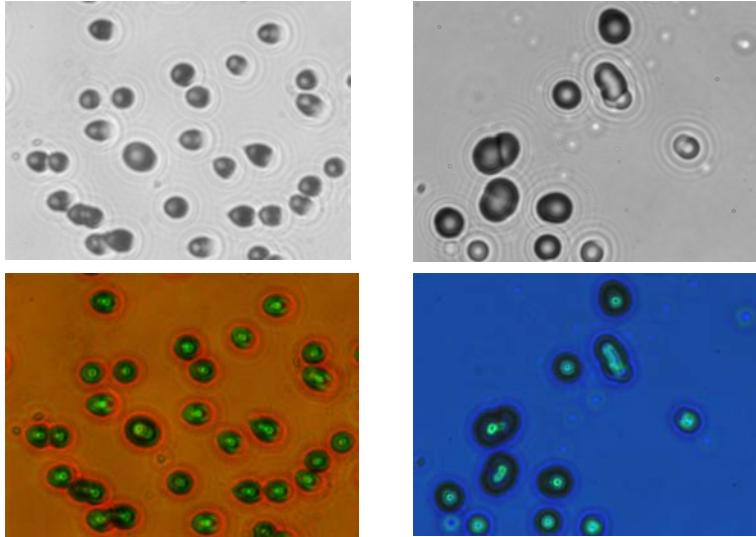
- After treatment with an etching agent, tracks remain as holes or pits and their size and shape can be measured.



## Ag wire/Pd/D in Magnetic Field



## Is a Feature Due to Background or to a Particle?

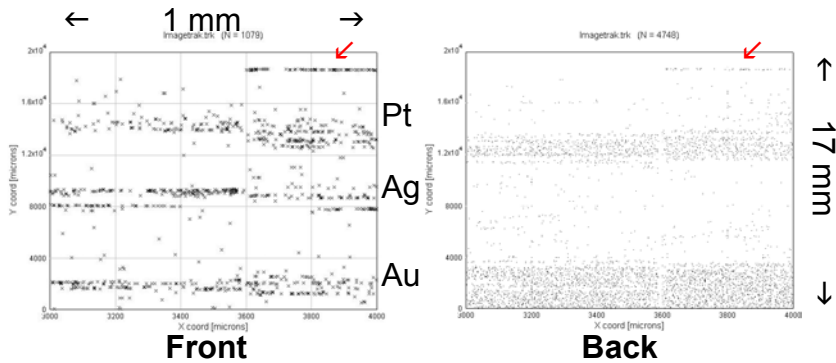


Features due to background are small, bright and shallow (they refract light from the shallow, curved, bottoms causing them to be brighter when the microscope is focused on the surface features). The deeper nuclear tracks are darker. If you focus deeper into the chip they show bright points of light at their centers.

## Summary of Control Experiments

- Pits are not due to radioactive contamination of the cell components
- Pits are not due to impingement of  $D_2$  gas on the surface of the CR-39
- Pits are not due to chemical reaction with electrochemically generated  $D_2$ ,  $O_2$ , or  $Cl_2$
- LiCl is not required to generate pits
- $D_2O$  yields higher density of pits than  $H_2O$
- Pd/D co-dep gave higher density of pits than Pd wire

## Front and Back Surface Comparison: 1 mm by 17 mm scan



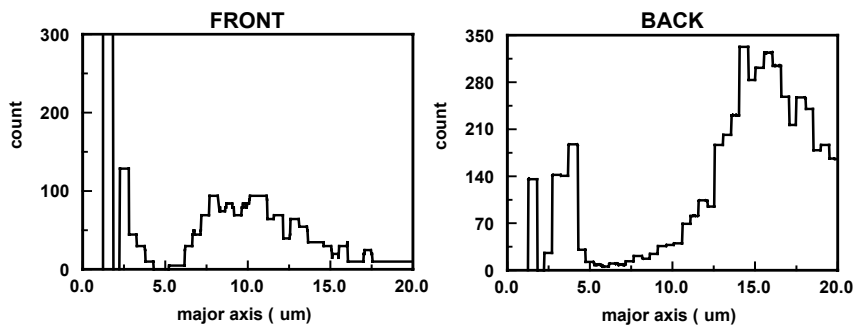
Same (x,y) locations, front and back.

↙ same feature seen on both sides for Pt wire.

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

*No tracks from Ag on back!*

## Counts vs Major Axis



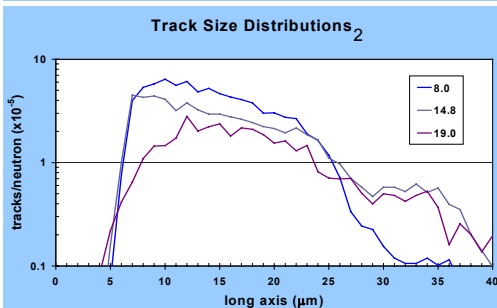
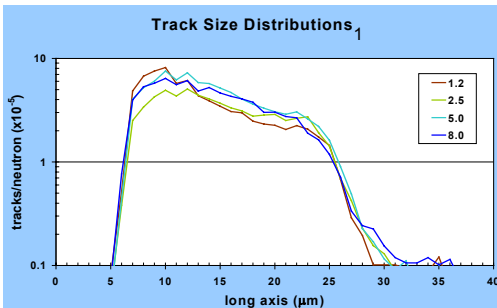
Front: d1, 2  $\mu\text{m}$ ; d2, 3.5  $\mu\text{m}$ ; d3, 8 - 12  $\mu\text{m}$

*assignment >4.2 MeV  $\alpha$ ?*

Back: d1, 2  $\mu\text{m}$ ; d2 3.8  $\mu\text{m}$ ; d3, 12 - 20+  $\mu\text{m}$

*assignment >40 MeV  $\alpha$ ? >10 MeV  $p^+$ ? Neutrons?*

# Neutron Track Size



CR-39 n efficiency  $10^{-4}$  -  $10^{-5}$

n tracks caused by knock-ons with CR-39 atoms:

$^1\text{H}$ ,  $^{12}\text{C}$ ,  $^{16}\text{O}$

$n_e > 12$  MeV will break  $^{12}\text{C}$  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.

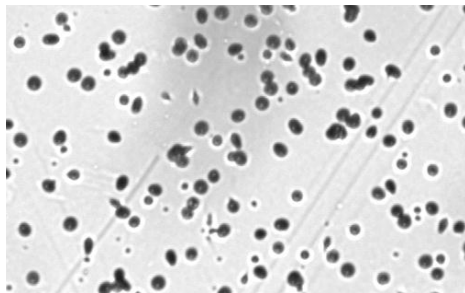
Track size function of  $n_e$ .

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

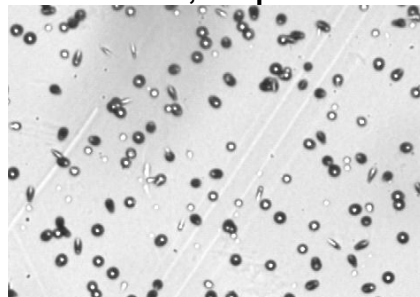
<sup>1,2</sup> Phillips, et. al., "Neutron Spectrometry Using CR-39 Track Etch Detectors", 14th SSD, 2004.

## Neutrons?

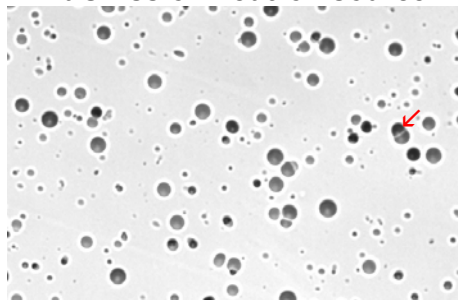
back side



back, deeper focus



<sup>238</sup>PuO fission neutron source <sup>1</sup>



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.

<sup>1</sup> Phillips, et. al., "Neutron Spectrometry Using CR-39 Track Etch Detectors", 14th SSD, 2004.

## Conclusions

- **Early Pd/D co-deposition experiments demonstrated excess enthalpy, formation of hot spots, emission of low intensity radiation, and production of tritium**
- **Excess enthalpy is generated by highly energetic fast reactions that resemble “mini-explosions”. This view is supported by IR imaging (hot spots) and by the response of the pressure/temperature sensitive substrates (piezoelectric material) onto which the Pd/D films are co-deposited**
- **An external electric/magnetic field changes the shape of the individual globules of the “cauliflower” structure of the Pd/D co-deposited material**
- **New elements are observed that are associated with the morphological features formed by the action of the external E/B fields**
- **Using CR-39 detectors, tracks are obtained that are consistent with both nuclear charged particles and neutron knock-on tracks**