

# **Summary of Tritium Evolution from Various Experiments**

Thomas N. Claytor<sup>1</sup>, Malcolm M. Fowler<sup>2</sup>,

<sup>1</sup> High Mesa Technology, Guest Scientist, Los Alamos, NM USA

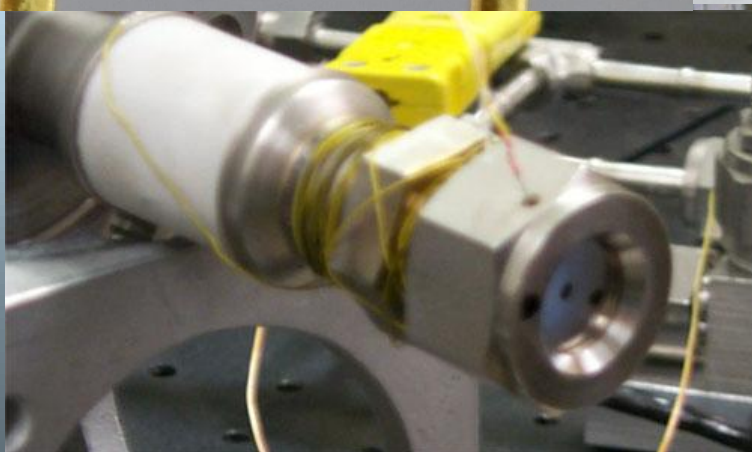
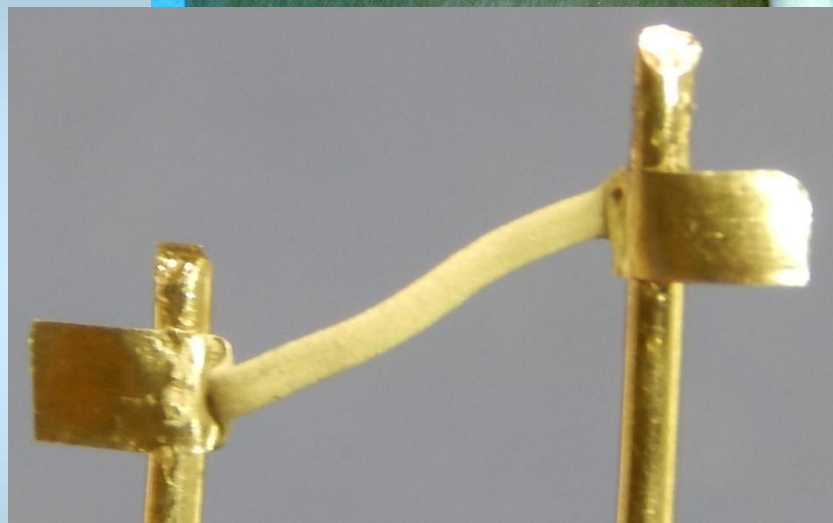
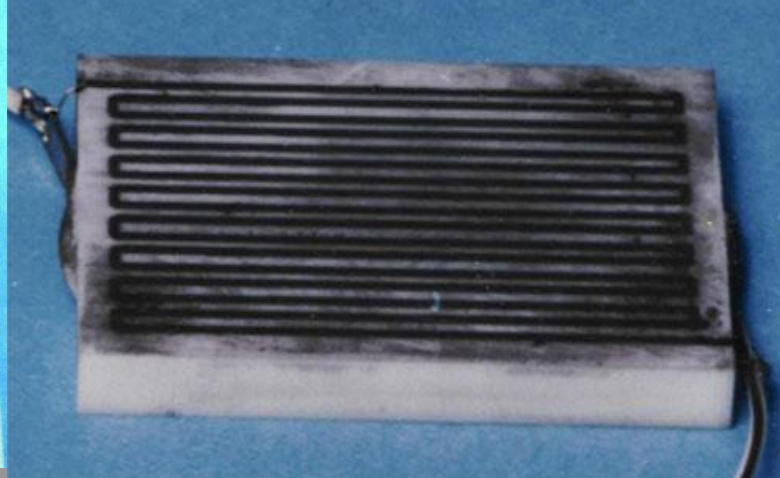
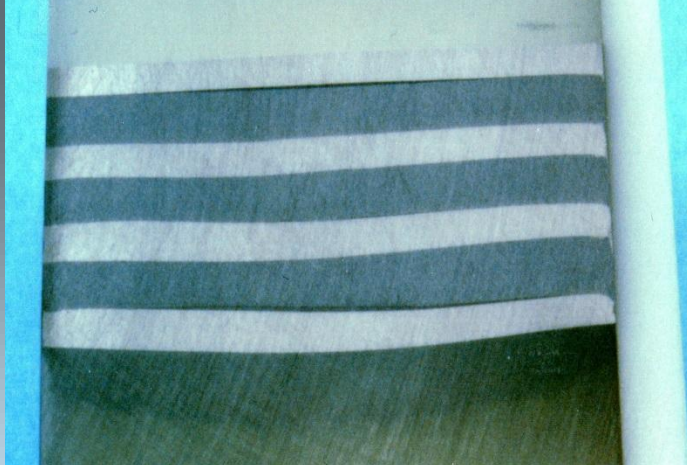
<sup>2</sup> McFarland Instrumentation Services, Inc.

12<sup>th</sup> International Workshop on Anomalies  
in Hydrogen Loaded Metals

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# Presentation fatigue

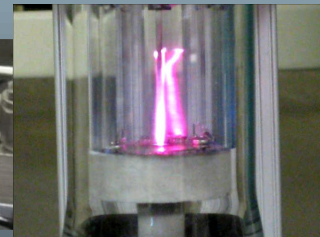
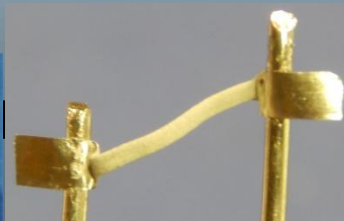
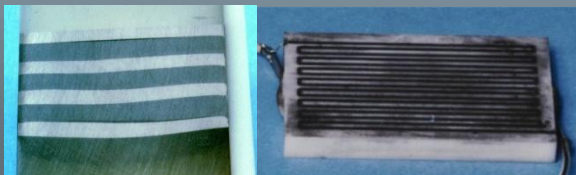




# What we have done and where are we going:

	Pd-Si powder solid state cells	Pd powder tracks	Pd wire cells	Pd diffusion disk	Plasma cells	G75 cells
Pd load	20 g	2 g	250 mg	1.5 g	150mg	2 g
Tritium pCi/hr-g	Up to 50	to 30	to 44	200	to 530	15
Excitation	Fast, short, high power pulse			Heating discharge	FSHPP	Heat
n/t ratio	$3 \times 10^{-8}$					

\_\_\_\_\_ 3% ? \_\_\_\_\_



Stated Alloy Composition	Highest Tritium Rate pCi/h	Alloy composition All rolled foil	Tritium rate pCi/h
PdRhCoB (5%,5%,0.045)	80	Hf	+10.0
PdRhCoB (5%,5%,0.18)	6.2	W	7.0
PdCu (10%)	6.2	Ta	5.0
PdRhCoB (5%,5%,0.26)	5.1	Ti	5.0
PdRh (0.1%)	4.8	Pt	4.6
PdRhCoB (5%,1.1%,0.11)	4.5	V	2.5
PdHg (0.1%)	3.8	Ni alloy 1: Ni 79.3, Fe 15.6,Cr 3.0, Mn 0.94	2.1
PdB (5%)	2.0	Ni	1.8
PdCu (1%)	1.4	Ni alloy 2: Ni 80.4, Fe 14.9, Mo 4.1, Mn 0.53	1.5
PdB (0.06%)	1.1	Nb	0.0
PdAl (0.1%)	1.0	Zr	0.0
PdFe (10%)	0.62	Fe	0.0
PdNi (4.6%)	0.53	Fe-Ni	0.0
PdLi (0.3%)	0.45	Ag	0.0
PdW (0.1%)	0.28		
PdCo (1.1%)	0.25		
PdRhCrB(5%,5%, ?%)	0.21		
PdB (0.03%)	0.10		
PdRh (0.5%)	-0.17		
PdCr (2.1%)	-0.52		
PdRhB(10%,1.0)	-0.73		
PdNi (1.1%)	-2.3		
PdRhB(5%,0.49)	-2.4		
PdBe (0.4%)	-2.8		
PdBe (0.1%)	-5.4		
PdHf (0.1%)	-6.7		

# Various Metal “Shielding” Factors (Raiola et al 2006)

## Metals with Highest Uo

<b>Pd</b>	<b>800ev</b>
<b>Sb</b>	<b>720ev</b>
<b>Pt</b>	<b>670ev</b>
<b>Co</b>	<b>640ev</b>
<b>Ti</b>	<b>550ev</b>
<b>Ni</b>	<b>380ev</b>
<b>Rh</b>	<b>230ev</b>

## Metals showing little or no Effect

### Transition Metals

Ti	<30
Sc	<30
Hf	<30
Zr	<40

### Lanthanides

Nd	<30
Sm	<30
Ce	<30

### Rare Earths

Dy	<30
Tb	<30
Gd	<30

Showing: Atomic weight

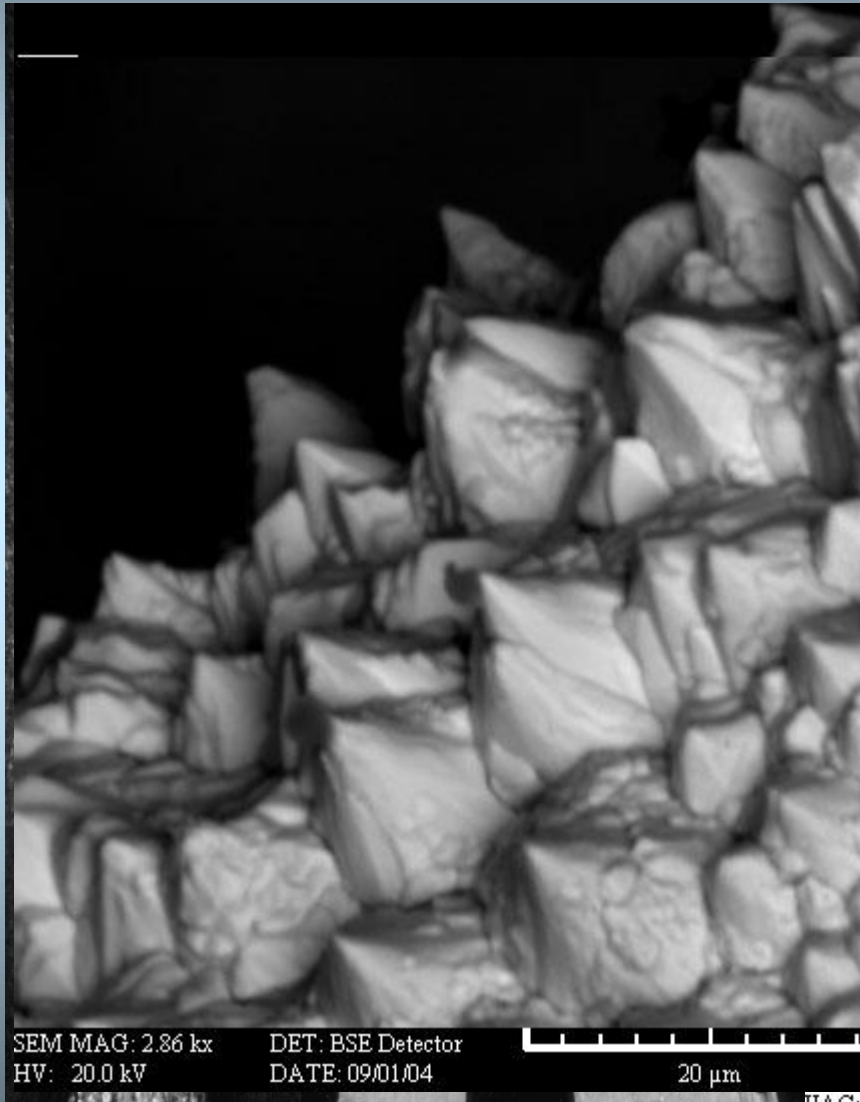
1	IA	1	H	1.0079	IIA	2	He	4.0026	VIIIB	2	He	4.0026
2		3	Li	6.941		4	Be	9.0122		10	Ne	20.1798
3		5	B	10.811		6	C	12.011		16	S	32.06
4		7	N	14.0067		8	O	15.9994		17	Cl	35.453
5		9	F	18.998403		10	Ne	20.1798		18	Ar	39.948
6		11	Na	22.989769	IIIA	12	Mg	24.304	IIIB	13	Al	26.98154
7		13	Al	26.98154	IVA	14	Si	28.0855	IVB	14	Si	28.0855
8		15	P	30.97376	VA	15	P	30.97376		15	P	30.97376
9		16	S	32.06	VIA	16	S	32.06		16	S	32.06
10		17	Cl	35.453	VIIA	17	Cl	35.453		17	Cl	35.453
11		18	Ar	39.948		18	Ar	39.948		18	Ar	39.948
12		19	K	39.0983		19	K	39.0983		19	K	39.0983
13		20	Ca	40.078		20	Ca	40.078		20	Ca	40.078
14		21	Sc	44.9559		21	Sc	44.9559		21	Sc	44.9559
15		22	Ti	47.88		22	Ti	47.88		22	Ti	47.88
16		23	V	50.9415		23	V	50.9415		23	V	50.9415
17		24	Cr	51.996		24	Cr	51.996		24	Cr	51.996
18		25	Mn	54.9380		25	Mn	54.9380		25	Mn	54.9380
19		26	Fe	55.847		26	Fe	55.847		26	Fe	55.847
20		27	Co	58.9332		27	Co	58.9332		27	Co	58.9332
21		28	Ni	58.71		28	Ni	58.71		28	Ni	58.71
22		29	Cu	63.546		29	Cu	63.546		29	Cu	63.546
23		30	Zn	65.38		30	Zn	65.38		30	Zn	65.38
24		31	Ga	69.723		31	Ga	69.723		31	Ga	69.723
25		32	Ge	72.63		32	Ge	72.63		32	Ge	72.63
26		33	As	74.9216		33	As	74.9216		33	As	74.9216
27		34	Se	78.96		34	Se	78.96		34	Se	78.96
28		35	Br	79.904		35	Br	79.904		35	Br	79.904
29		36	Kr	83.80		36	Kr	83.80		36	Kr	83.80
30		37	Rb	85.468		37	Rb	85.468		37	Rb	85.468
31		38	Sr	87.62		38	Sr	87.62		38	Sr	87.62
32		39	Y	88.9059		39	Y	88.9059		39	Y	88.9059
33		40	Zr	91.224		40	Zr	91.224		40	Zr	91.224
34		41	Nb	92.9064		41	Nb	92.9064		41	Nb	92.9064
35		42	Mo	95.94		42	Mo	95.94		42	Mo	95.94
36		43	Tc	98.9062		43	Tc	98.9062		43	Tc	98.9062
37		44	Ru	101.07		44	Ru	101.07		44	Ru	101.07
38		45	Rh	102.9055		45	Rh	102.9055		45	Rh	102.9055
39		46	Pd	106.42		46	Pd	106.42		46	Pd	106.42
40		47	Ag	107.8682		47	Ag	107.8682		47	Ag	107.8682
41		48	Cd	112.411		48	Cd	112.411		48	Cd	112.411
42		49	In	114.818		49	In	114.818		49	In	114.818
43		50	Sn	118.710		50	Sn	118.710		50	Sn	118.710
44		51	Sb	121.757		51	Sb	121.757		51	Sb	121.757
45		52	Te	127.60		52	Te	127.60		52	Te	127.60
46		53	I	126.9045		53	I	126.9045		53	I	126.9045
47		54	Xe	131.29		54	Xe	131.29		54	Xe	131.29
48		55	Cs	132.90545		55	Cs	132.90545		55	Cs	132.90545
49		56	Ba	137.327		56	Ba	137.327		56	Ba	137.327
50		57	La	138.9055		57	La	138.9055		57	La	138.9055
51		58	Ce	140.12		58	Ce	140.12		58	Ce	140.12
52		59	Pr	140.9077		59	Pr	140.9077		59	Pr	140.9077
53		60	Nd	144.24		60	Nd	144.24		60	Nd	144.24
54		61	Pm	(145)		61	Pm	(145)		61	Pm	(145)
55		62	Sm	150.4		62	Sm	150.4		62	Sm	150.4
56		63	Eu	151.96		63	Eu	151.96		63	Eu	151.96
57		64	Gd	157.25		64	Gd	157.25		64	Gd	157.25
58		65	Tb	158.9254		65	Tb	158.9254		65	Tb	158.9254
59		66	Dy	162.50		66	Dy	162.50		66	Dy	162.50
60		67	Ho	164.9304		67	Ho	164.9304		67	Ho	164.9304
61		68	Er	167.26		68	Er	167.26		68	Er	167.26
62		69	Tm	168.9342		69	Tm	168.9342		69	Tm	168.9342
63		70	Yb	173.04		70	Yb	173.04		70	Yb	173.04
64		71	Lu	174.967		71	Lu	174.967		71	Lu	174.967
65		72	Hf	178.49		72	Hf	178.49		72	Hf	178.49
66		73	Ta	180.947		73	Ta	180.947		73	Ta	180.947
67		74	W	183.85		74	W	183.85		74	W	183.85
68		75	Re	186.207		75	Re	186.207		75	Re	186.207
69		76	Os	190.2		76	Os	190.2		76	Os	190.2
70		77	Ir	192.22		77	Ir	192.22		77	Ir	192.22
71		78	Pt	195.084		78	Pt	195.084		78	Pt	195.084
72		79	Au	196.96657		79	Au	196.96657		79	Au	196.96657
73		80	Hg	200.59		80	Hg	200.59		80	Hg	200.59
74		81	Tl	204.377		81	Tl	204.377		81	Tl	204.377
75		82	Pb	207.2		82	Pb	207.2		82	Pb	207.2
76		83	Bi	208.9804		83	Bi	208.9804		83	Bi	208.9804
77		84	Po	(209)		84	Po	(209)		84	Po	(209)
78		85	At	(210)		85	At	(210)		85	At	(210)
79		86	Rn	(222)		86	Rn	(222)		86	Rn	(222)
80		87	Fr	(223)		87	Fr	(223)		87	Fr	(223)
81		88	Ra	(226)		88	Ra	(226)		88	Ra	(226)
82		89	Ac	(227)		89	Ac	(227)		89	Ac	(227)
83		90	Th	232.0377		90	Th	232.0377		90	Th	232.0377
84		91	Pa	231.0369		91	Pa	231.0369		91	Pa	231.0369
85		92	U	238.0289		92	U	238.0289		92	U	238.0289
86		93	Np	237.0482		93	Np	237.0482		93	Np	237.0482
87		94	Pu	(244)		94	Pu	(244)		94	Pu	(244)
88		95	Am	(243)		95	Am	(243)		95	Am	(243)
89		96	Cm	(247)		96	Cm	(247)		96	Cm	(247)
90		97	Bk	(247)		97	Bk	(247)		97	Bk	(247)
91		98	Cf	(251)		98	Cf	(251)		98	Cf	(251)
92		99	Es	(254)		99	Es	(254)		99	Es	(254)
93		100	Fm	(257)		100	Fm	(257)		100	Fm	(257)
94		101	Md	(258)		101	Md	(258)		101	Md	(258)
95		102	No	(259)		102	No	(259)		102	No	(259)
96		103	Lr	(260)		103	Lr	(260)		103	Lr	(260)

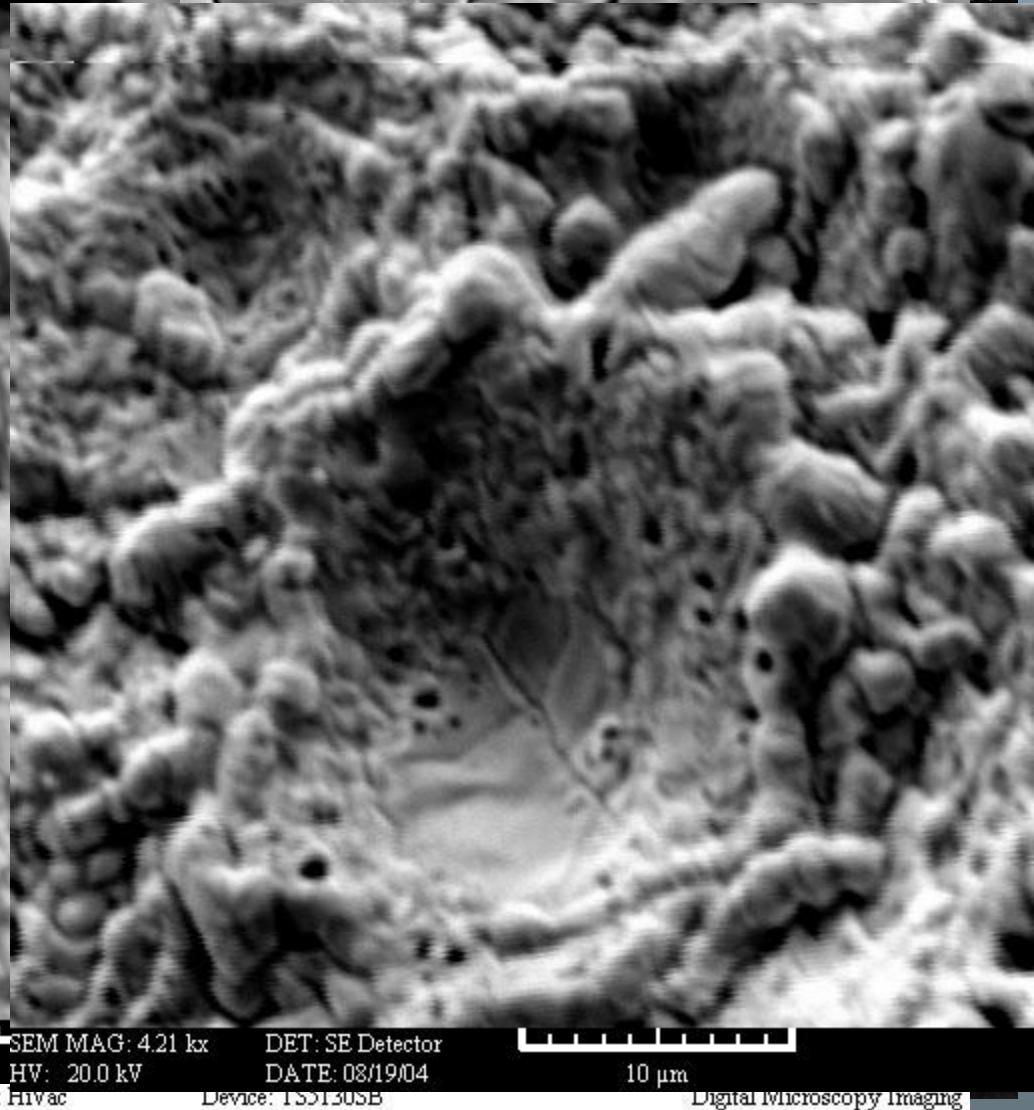
Lanthanide Series	58	59	60	61	62	63	64	65	66	67	68	69	70	71
	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
	140.12	140.9077	144.24	(145)	150.4	151.96	157.25	158.9254	162.50	164.9304	167.26	168.9342	173.04	174.967
Actinide Series	90	91	92	93	94	95	96	97	98	99	100	101	102	103
	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
	232.0377	231.0369	238.0289	237.0482	(244)	(243)	(247)	(247)	(251)	(254)	(257)	(258)	(259)	(260)

# Some Samples of Interest:

cathode



anode



## Modes of Operation: Arcing

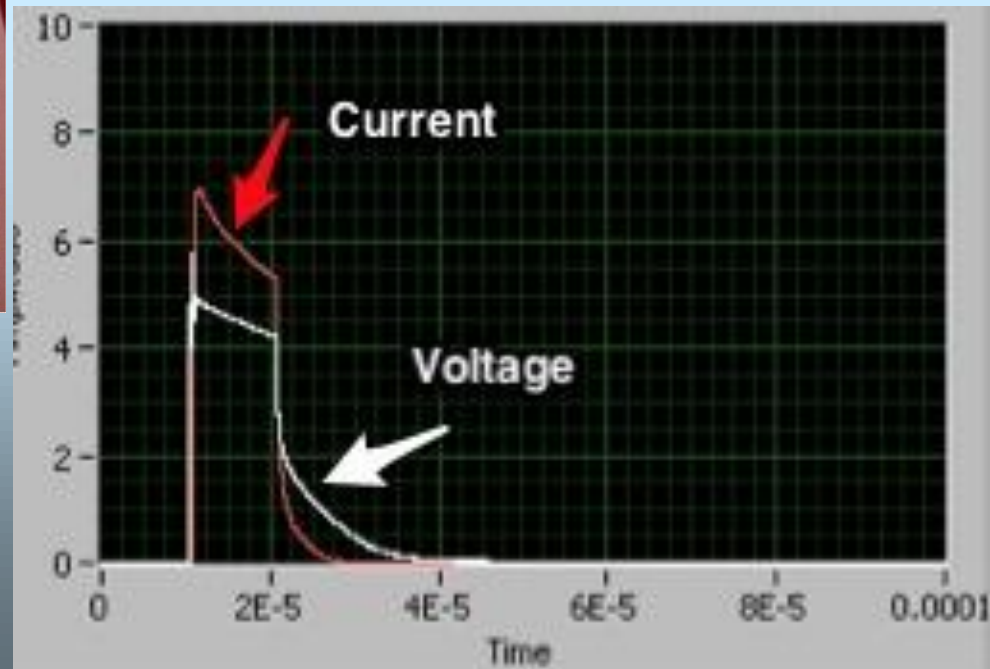
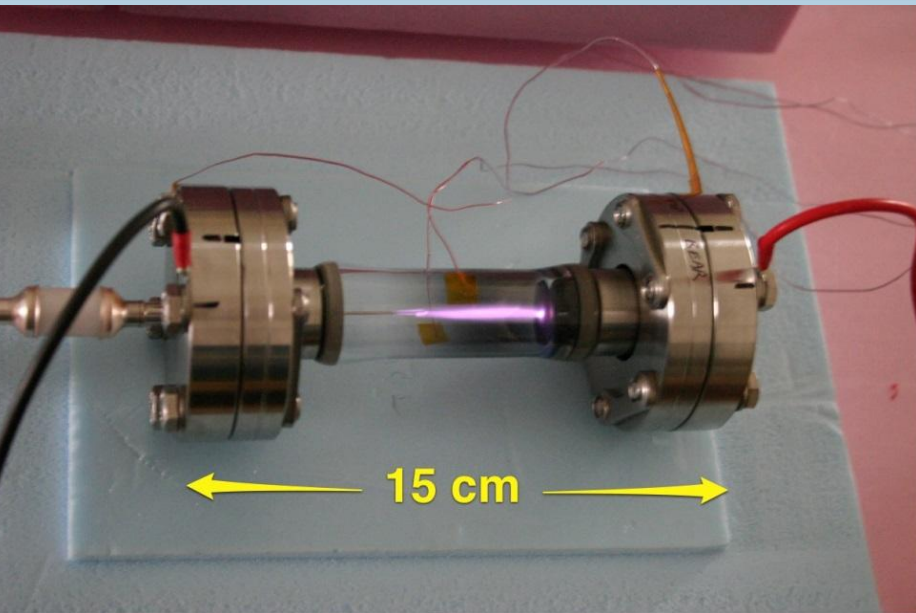


Modes of operation: ion channel and attachment

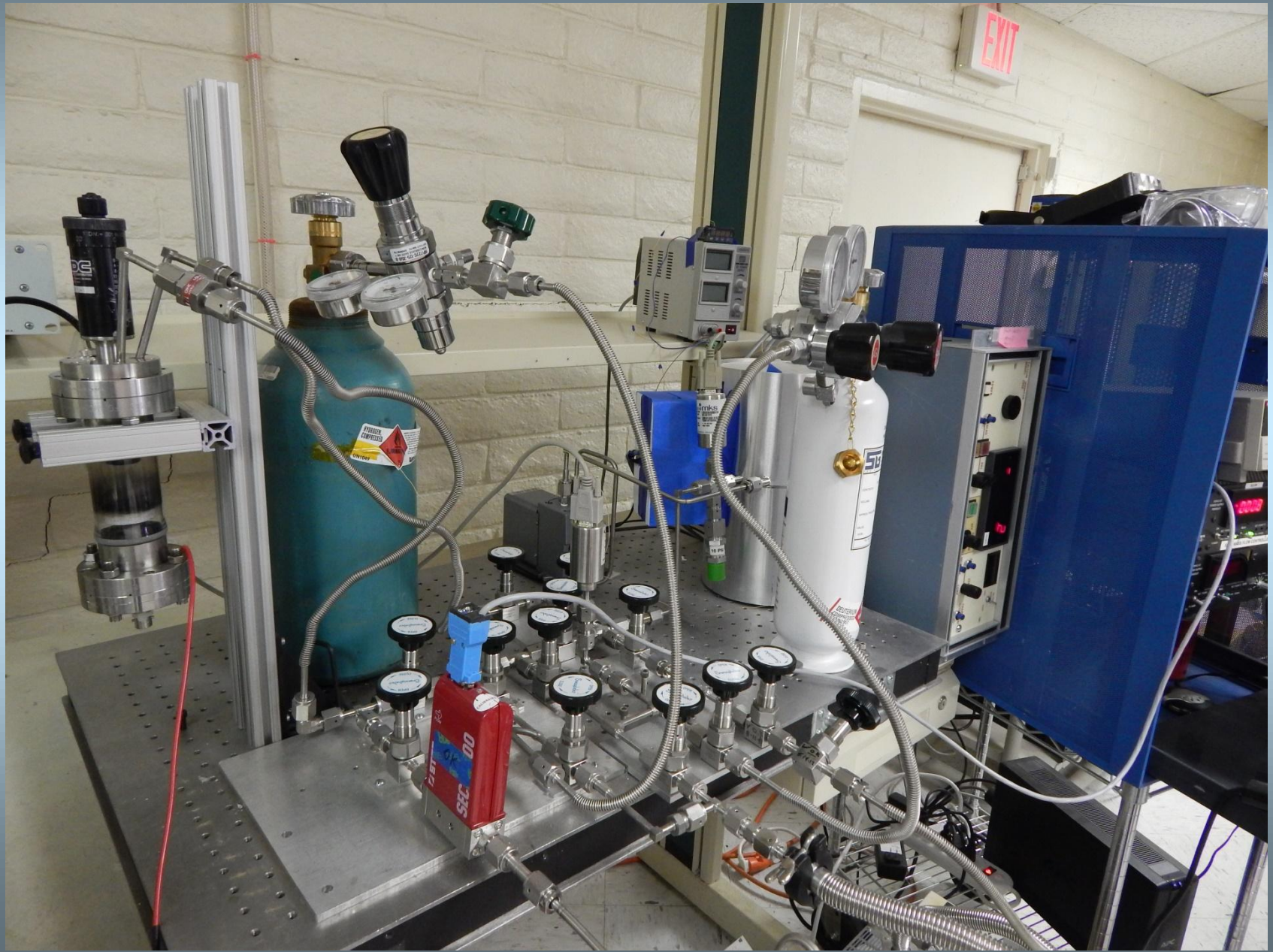


# Plasma characteristics (Not a glow discharge)

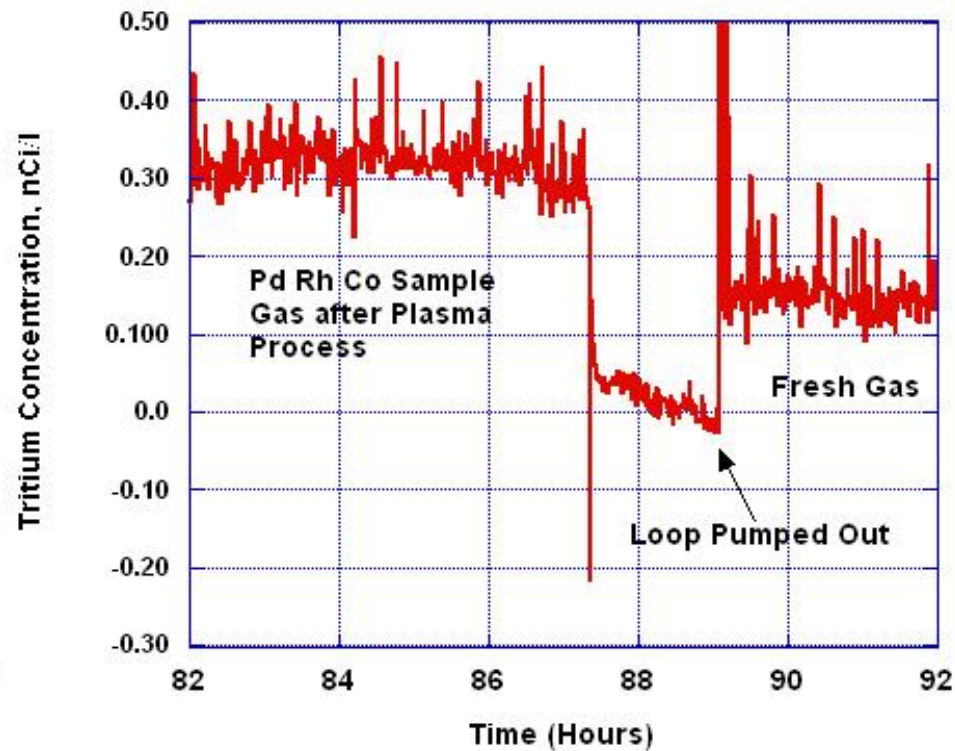
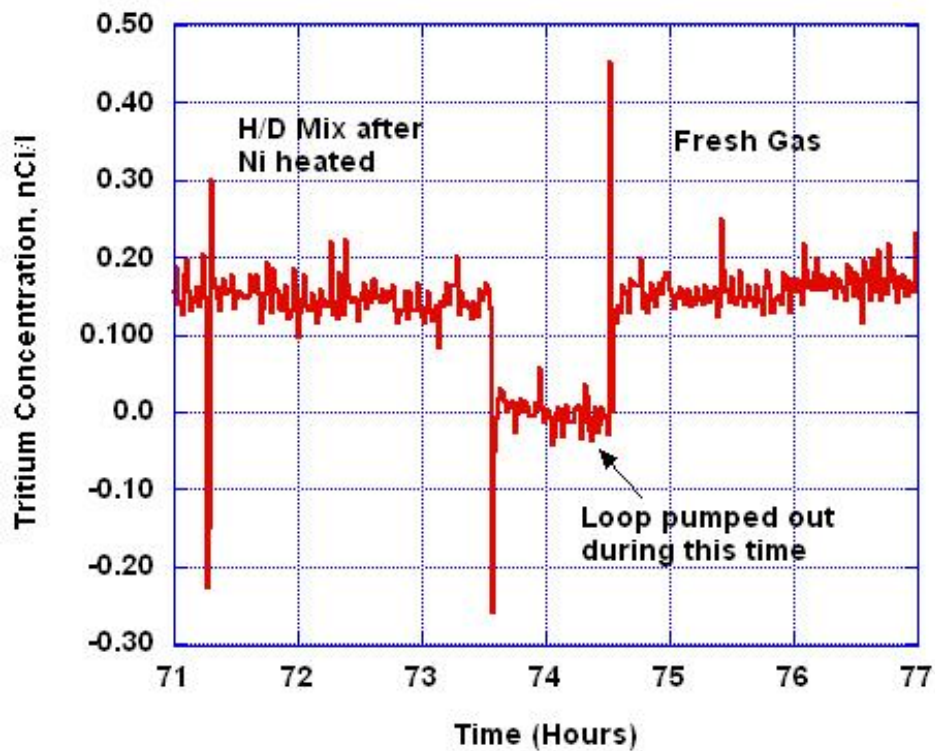
- 150-450 torr
- 900-1300 volts, 5-12 amps
- 5-20  $\mu\text{s}$  pulse @ 50-100 Hz
- Peak Power up to **15000 W**
- Constant power operation
- Sample V & I @ 14-bit, 100 M-sample/sec



# Femtotech Gas Analysis System



# Tritium Femtotech Data



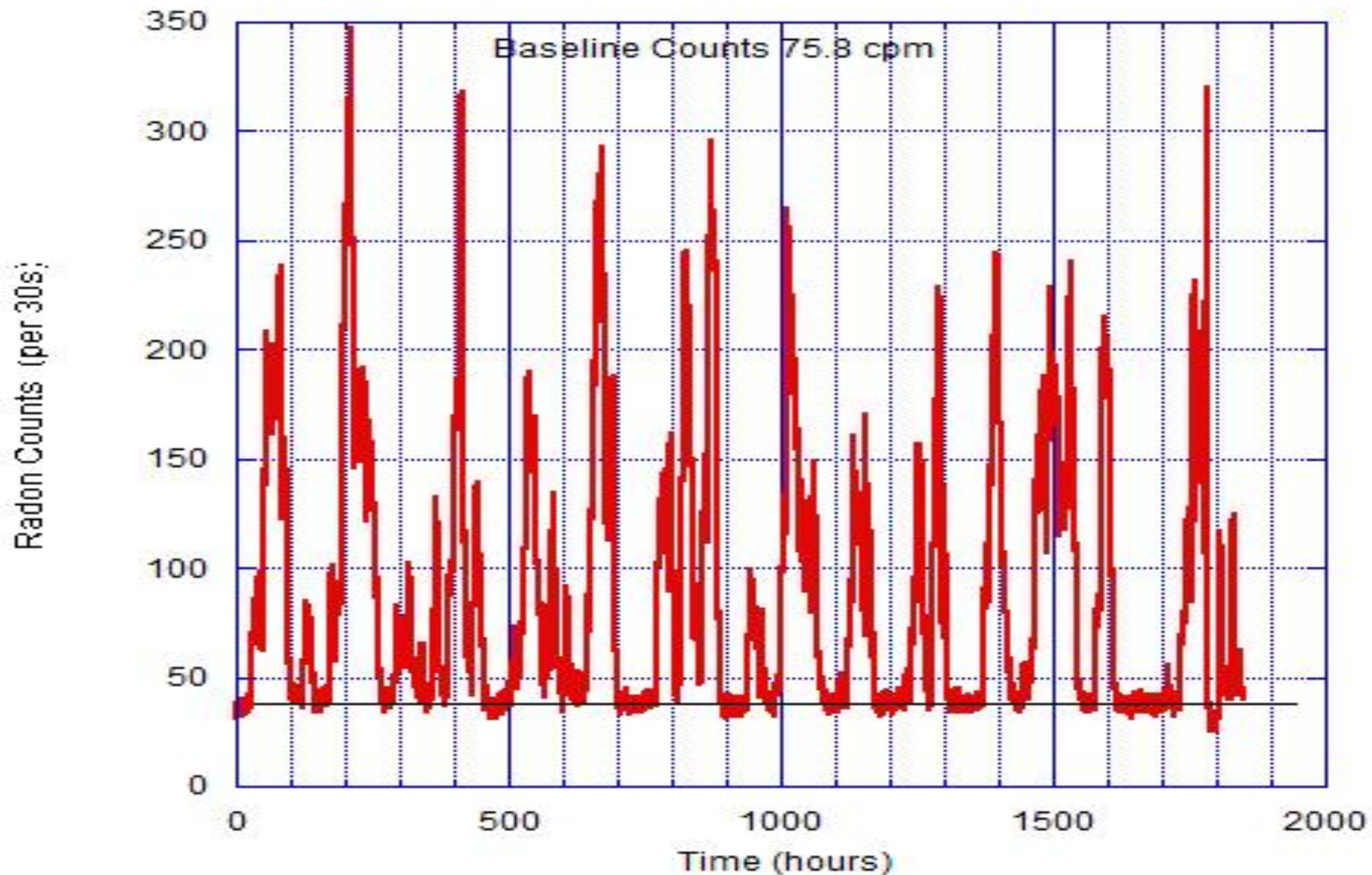
Beckman LSC 6500

1cc water sample in 10cc Ultima Gold Fluid

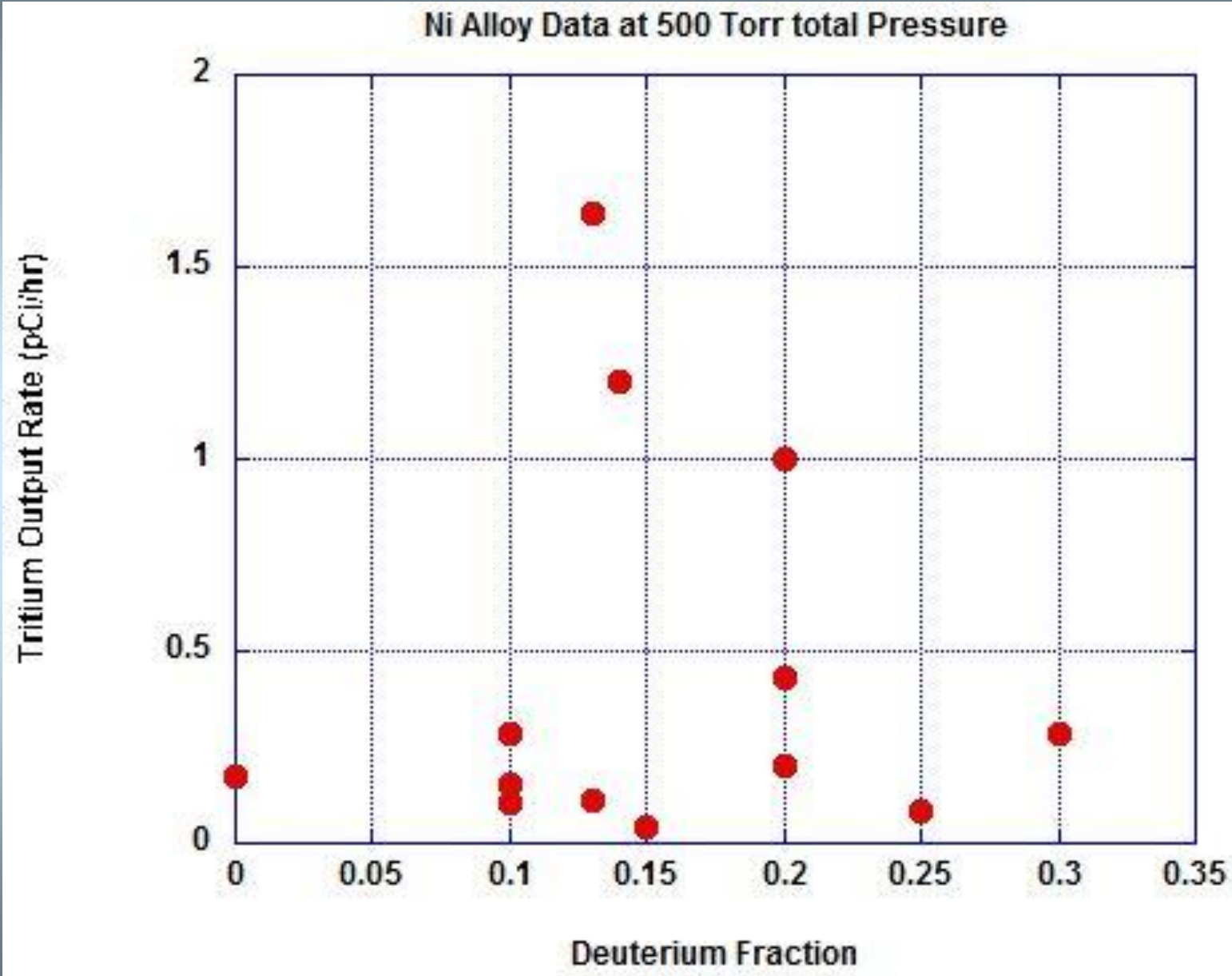


# Radon and Daughters can be a Problem for the Beckman

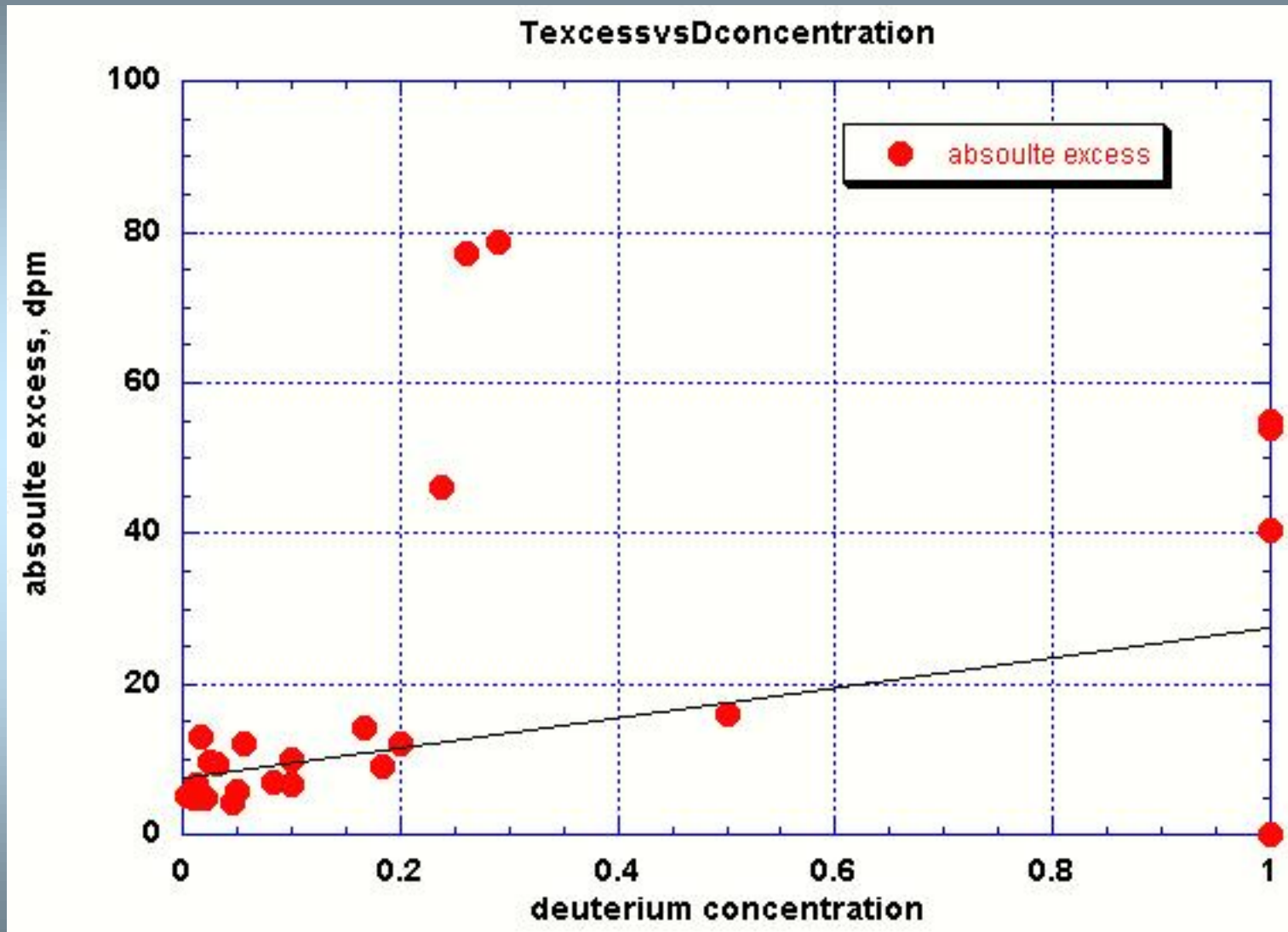
**Aw table main lab 11 18 16 to 2 2 17**



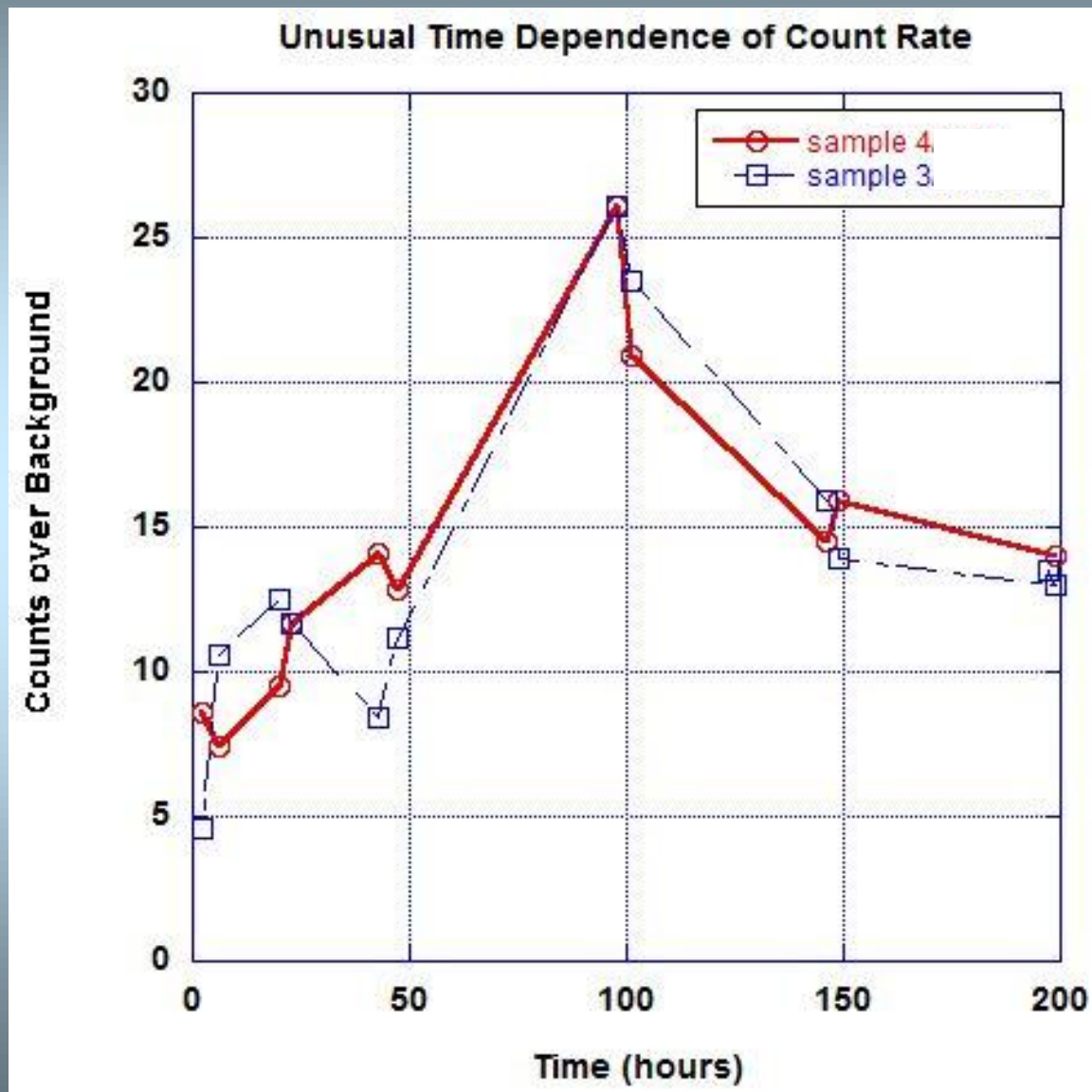
# Tritium output as a function of $D_2$ in $H_2$



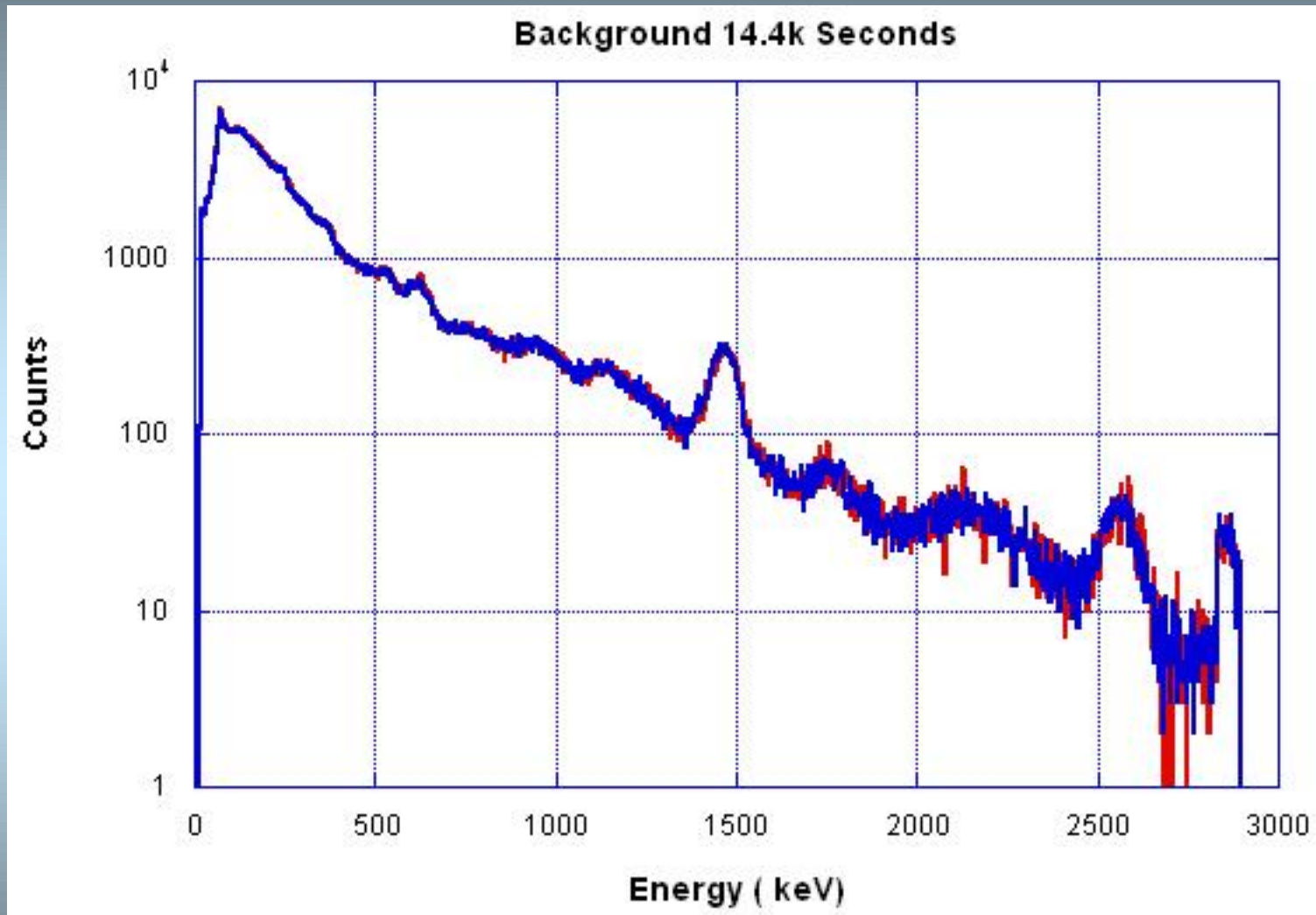
# G75 tritium output as a function of D<sub>2</sub> fraction



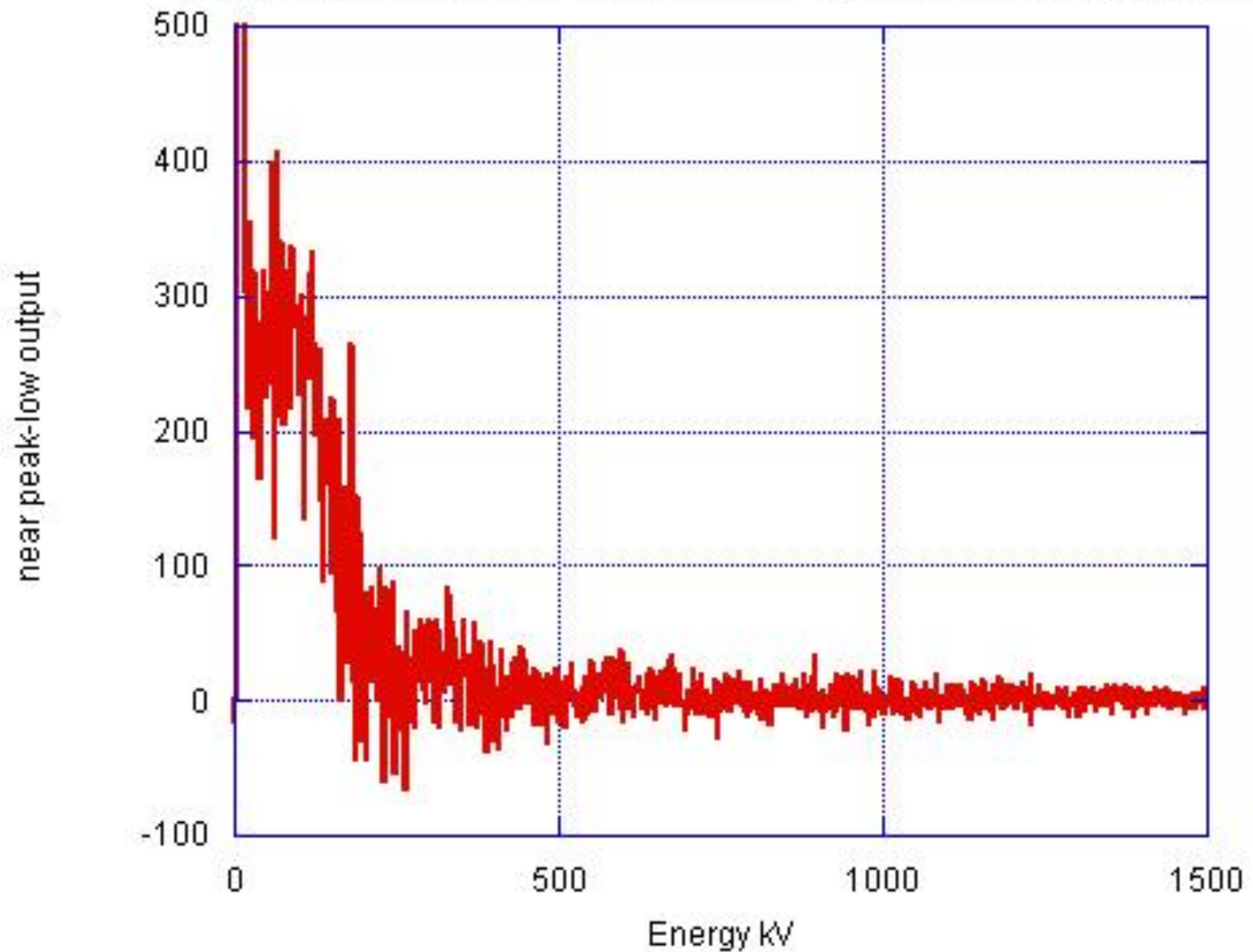
# Scintillation counting as a function of time:



# Nal Detector Data

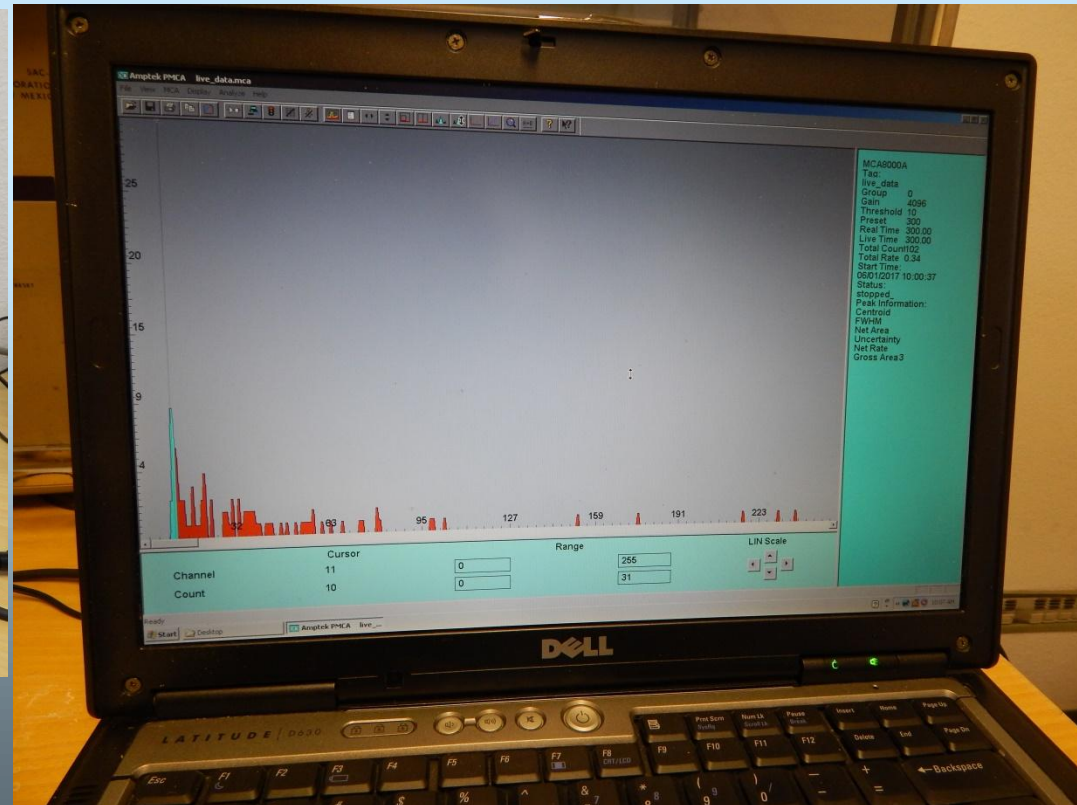


# Spectral Difference Between Cell Operation and Background



# SSD Detector for Post Run Activity

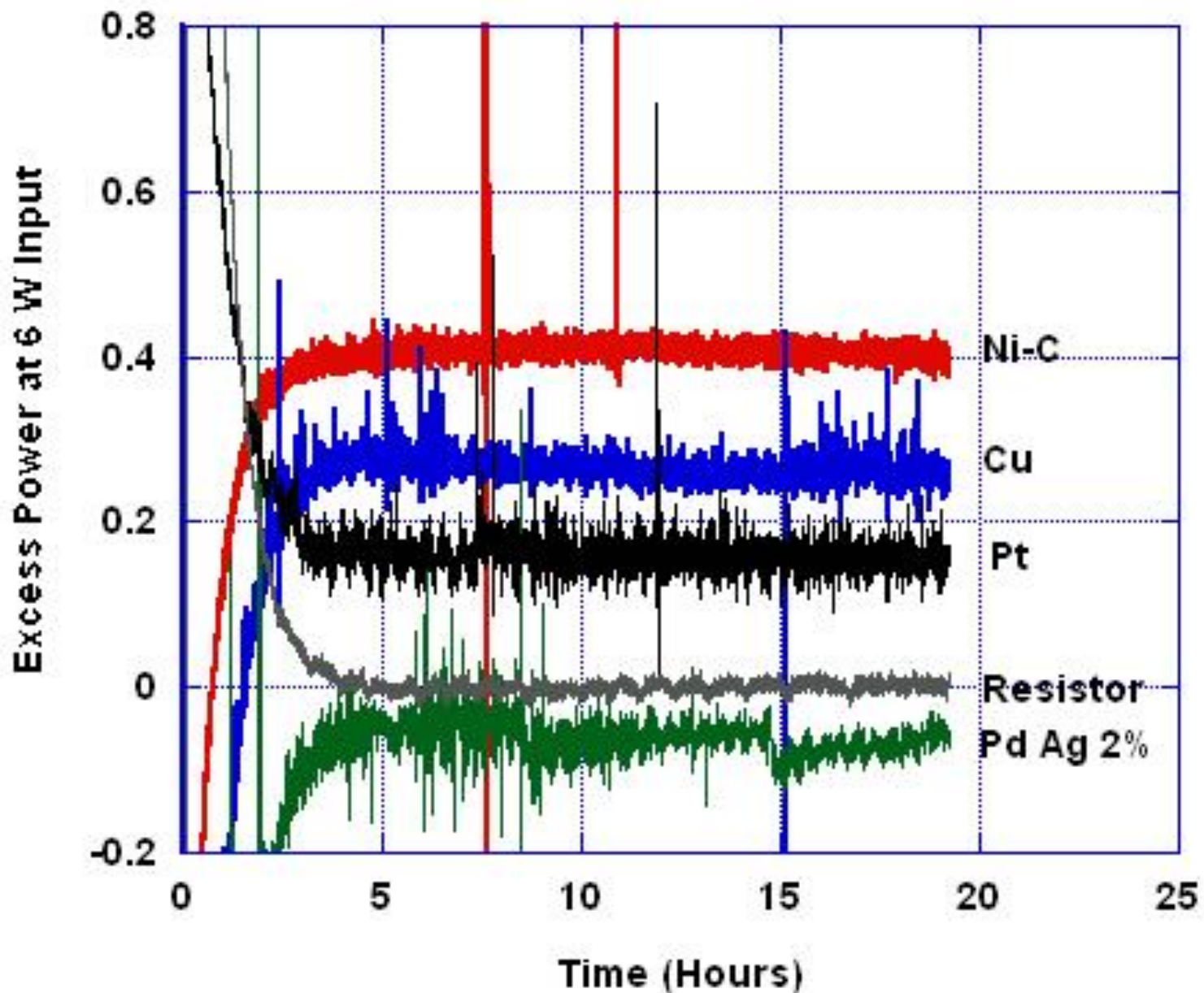
Highest rate over background 20kV-200kV is over twice background  
Immediately after removal from plasma cell.



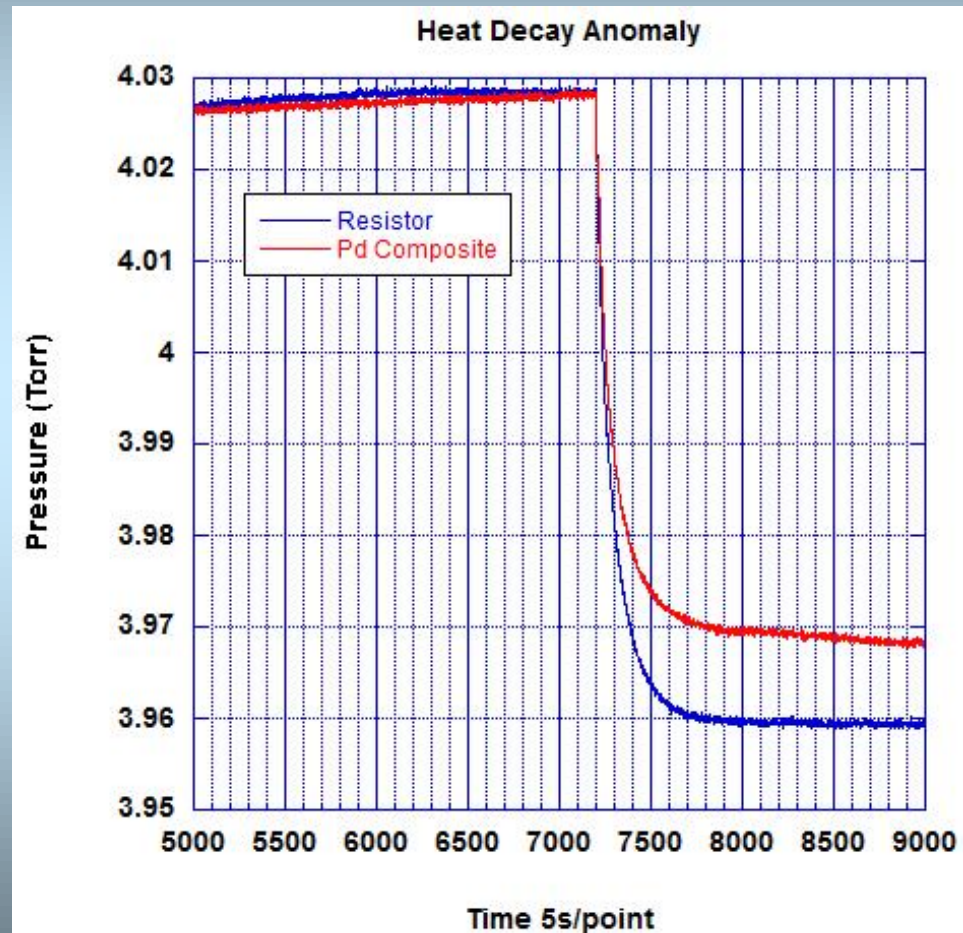
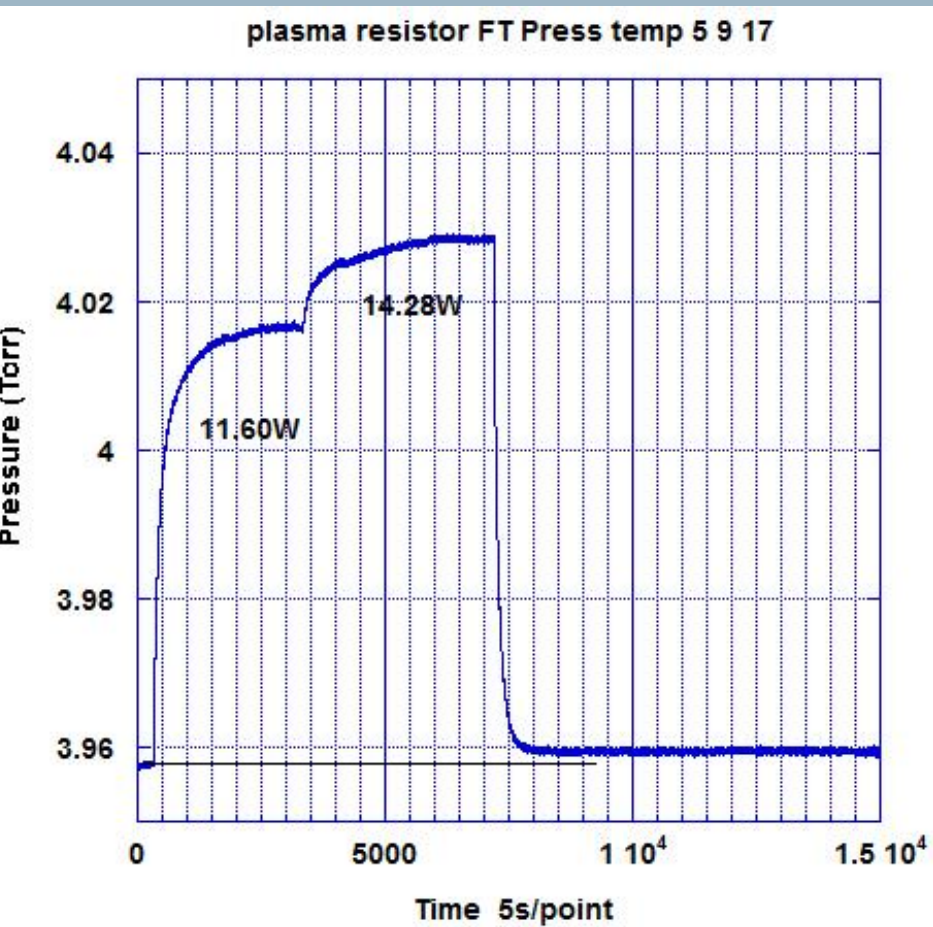
# Seebeck Calorimeter



# Heat Comparison 6W power input



# Pressure Rise/Decay Heat Comparison



# Is there Helium?

Gas analysis of initial gas and post-process gas from NiC sample  
Finnigan 270 can easily separate  $^4\text{He}$ ,  $^3\text{He}$  peaks from  $\text{D}_2$ , HD

Gas	$^4\text{He}$	$^3\text{He}$	
$\text{D}_2$ from bottle (lanl)	$90 \pm 50$ ppb ( <40ppb)	< 1ppb	Gettered
$\text{H}_2$ bottle (lanl)	150ppb (<40 ppb)	ND	Gettered
Plasma run H/D 24/75	$400 \pm 200$ ppb	<200 ppb	Non Gettered
Plasma run New system	~ 200 ppb	NA	Activated carbon

New  $^4\text{He}$  detection system built and tested, more confidence in results and lower error. Numbers in red are new results

# Conclusions

Ni Alloy is reproducible,

Tritium can be several sigma over background

Effect can be obtained in 1-2 days

Excess heat is small (~5%) but is it consistent with the Helium data?

If X-ray effect can be increased, then might serve as a quick demo

Pursue pressure indication for excess heat

Parameter space, effects of pressure, electrical driving conditions, temperature, etc. have only been partially explored.

All positive experiments have a common driver, can an engineered material be fabricated to take advantage of this basic understanding?

# Acknowledgments

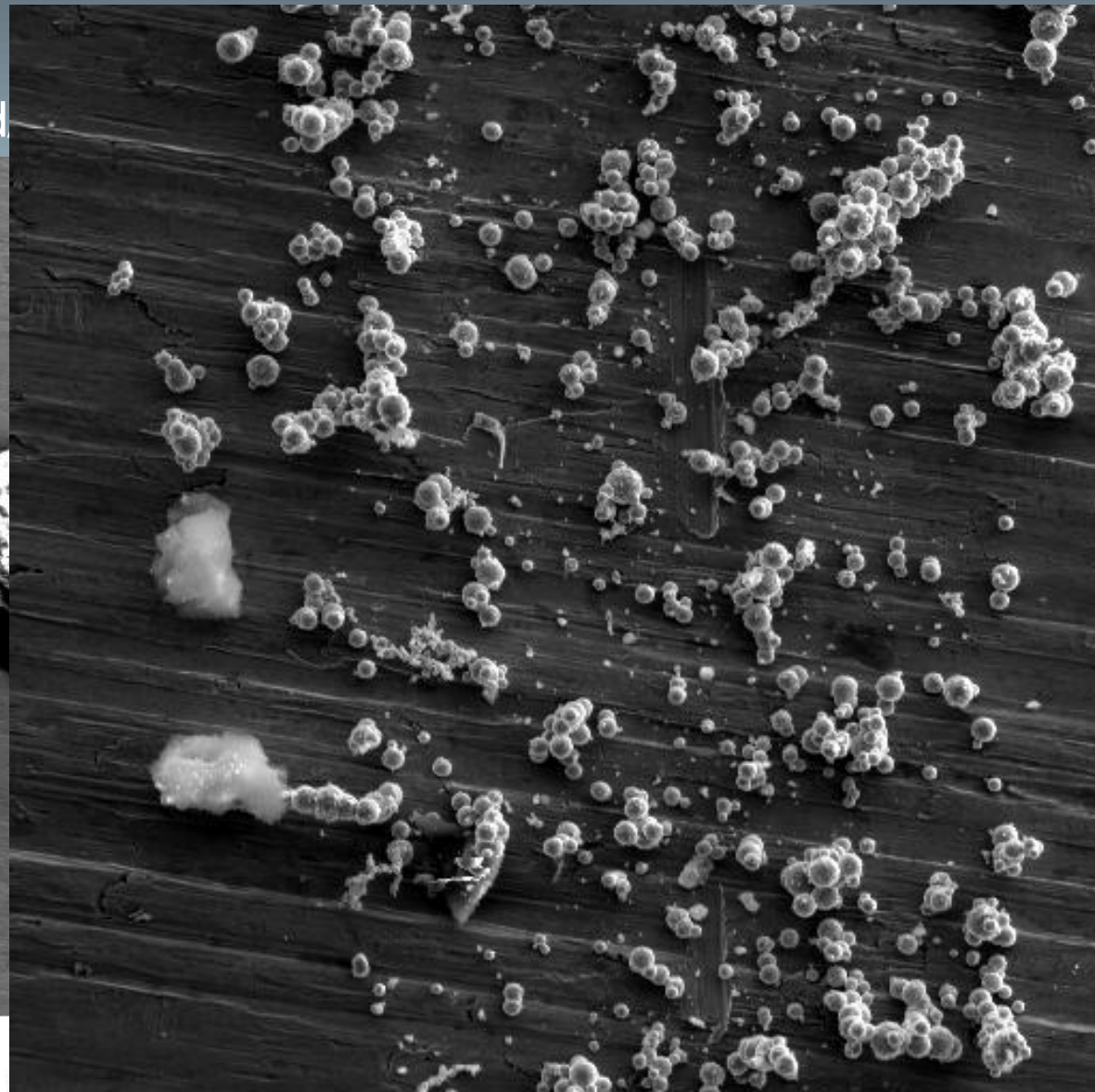
Industrial Heat, LLC  
Thomas Darden II  
J. T. Vaughn  
Dewey Weaver

Previous Support Provided by:  
Coolscence. LLC  
New Mexico Small Business Association  
LANL, LDRD Program

# Anomalous Results from Sonofusion (with Rodger Stringham)

Pd

SEM MAG: 384 x DET: SE Detector  
HV: 21.4 kV  
VAC: HiVac



SEM MAG: 376 x DET: SE Detector  
HV: 21.4 kV  
VAC: HiVac

100 um

Vega ©Tescan  
Digital Microscopy Imaging



Vega ©Tescan  
Digital Microscopy Imaging