

# Nuclear Battery Using D-Clusters in Nano-materials --- plus some comments about prior H<sub>2</sub>-Ni power cell studies

**George H. Miley<sup>1,3</sup>, Xiaoling. Yang<sup>1</sup>, Heinrich Hora<sup>2</sup>**

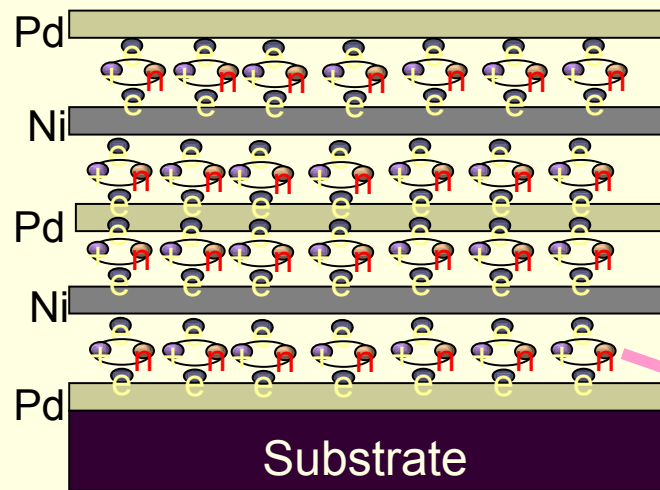
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# Outline

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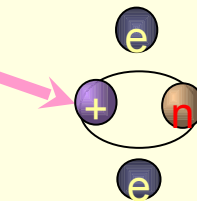
- Comments re prior light water Ni studies – Patterson Cell
- More recent experiments using thin-film plate type electrodes conditioned for cluster formation.
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SEL Theory lead the design of our early experiments. Patterson had already used multilayer films so that work fit right in also. Electrolytic loading used instead of gas pressure – but once loaded the mechanisms should be much the same.

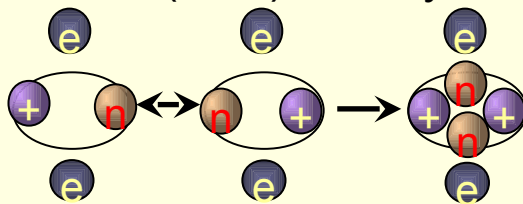


Swimming Electron Layer  
(SEL) Theory

SEL - High density electron clouds – exists between metals of different Fermi energy, providing the necessary screening



Zoom-in View



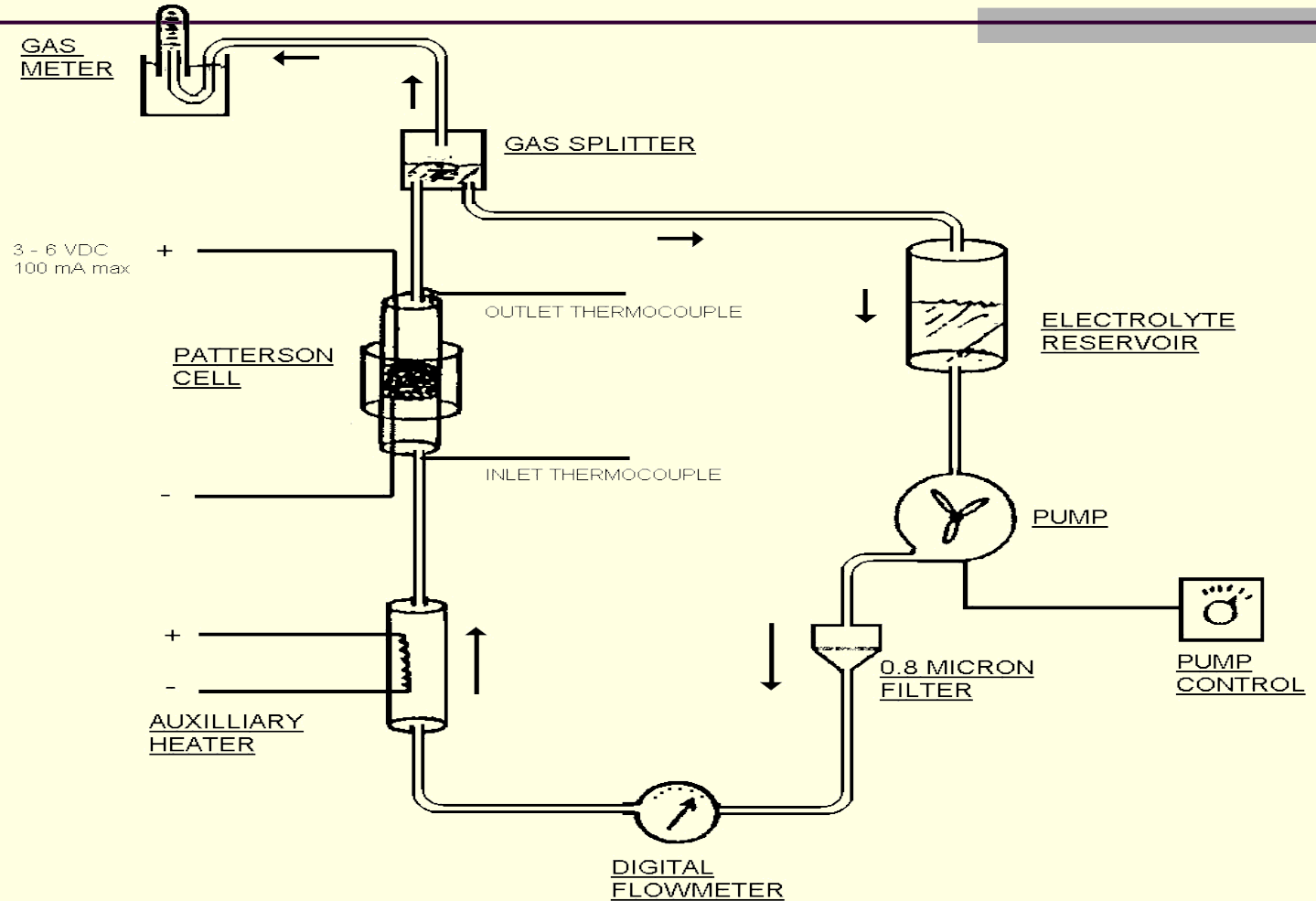
- Comments – Patterson Cell Studies – Light water- Ni system

- Key point – identification of reaction products and

- connection to heat release.

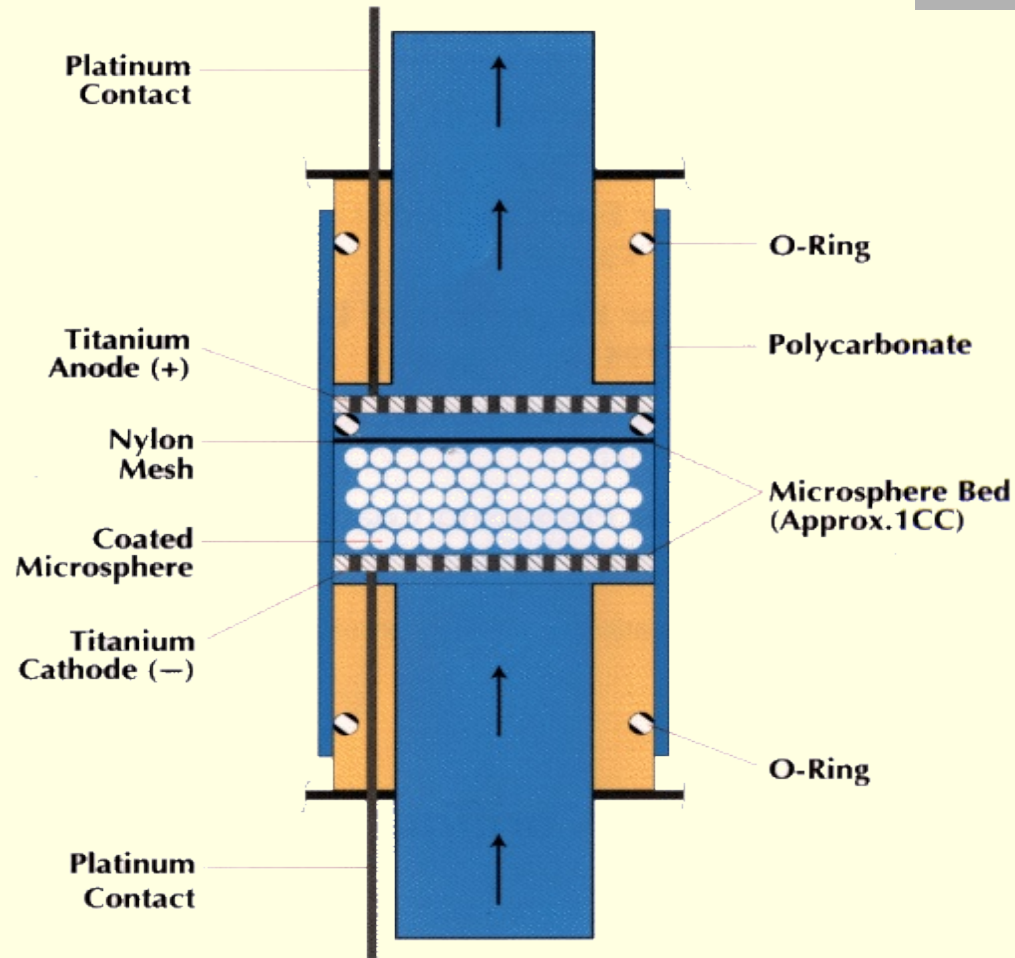
- [Jim Patterson and his grandson, Jim Redding, founded CETI to develop this

# Process Flow Sheet of Electrolysis

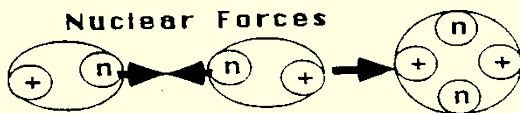


# Patterson Power Cell™

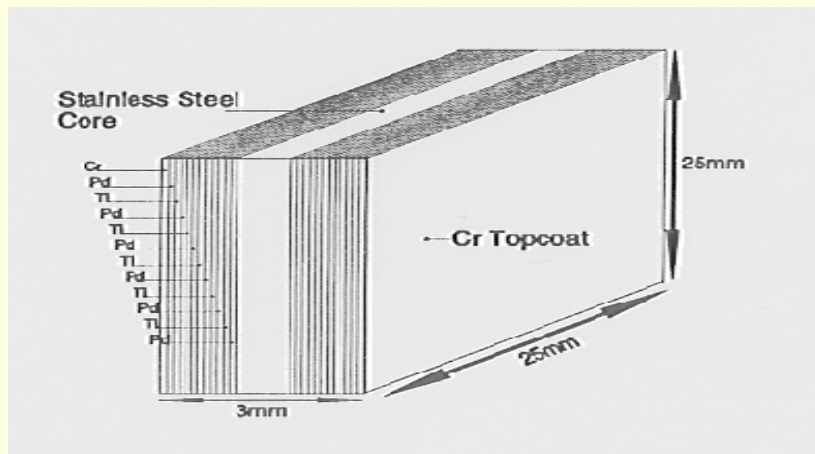
## Design



# SEL Theory and Experiments to Design Multilayer Thin-film Electrodes

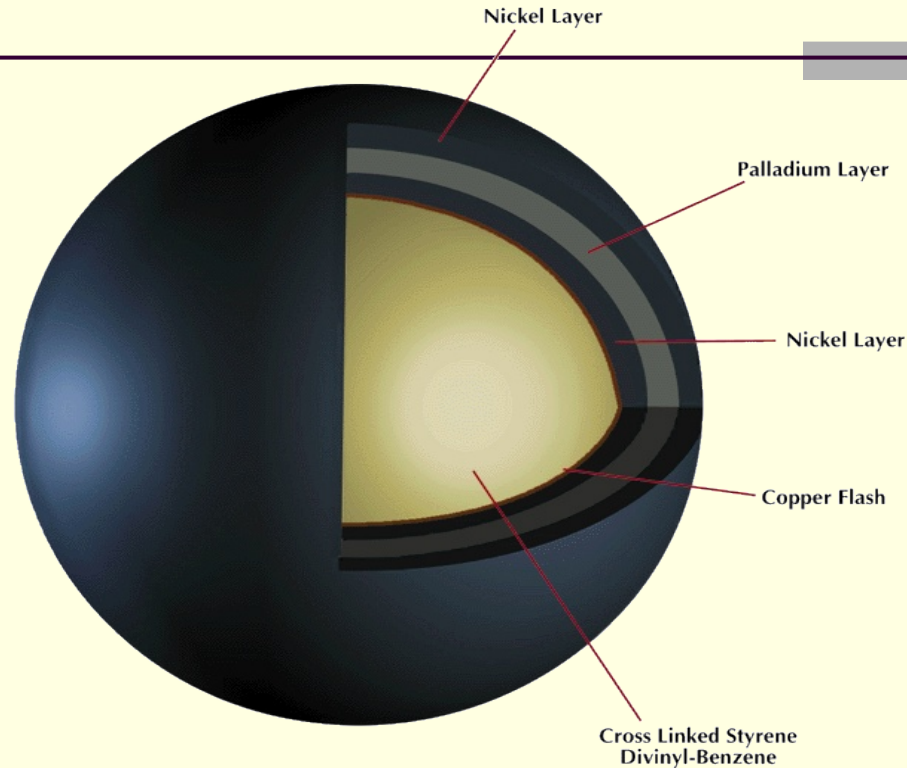


**Fusion of two nuclei, shielded by the swimming electron layer**



**Multilayer thin-film electrode design with alternating layers of Pd & Ni or Ti with a topcoat of Cr**

# Microsphere Design



**CETI uses an electrolytic coating process to coat metals on the microspheres. My sputter coating technique achieves better control of coating thickness and sharp interfaces compared to the electrolytic process. – however the excess heat is cut by an order of magnitude!**



Excess heats of 1-2 kW were consistently produced with these cells. How? Light water and Ni should not produce a reaction!! The next slides explain my search for an answer. I propose that similar studies should be done for rossi's cell.

# Rational for Combined SIMS-NAA

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- Analysis for a large number of isotopes needed.
- NAA is time consuming and was limited to nine elements with appropriate cross sections where reference standards were available.
- SIMS, with ultra low detection limits, could detect all isotopes rapidly, but it provides relative isotope concentrations and abundance ratios are more precisely than it does absolute concentrations.
- Thus the SIMS concentration values were normalized to the more accurate NAA results.

# SIMS Analysis

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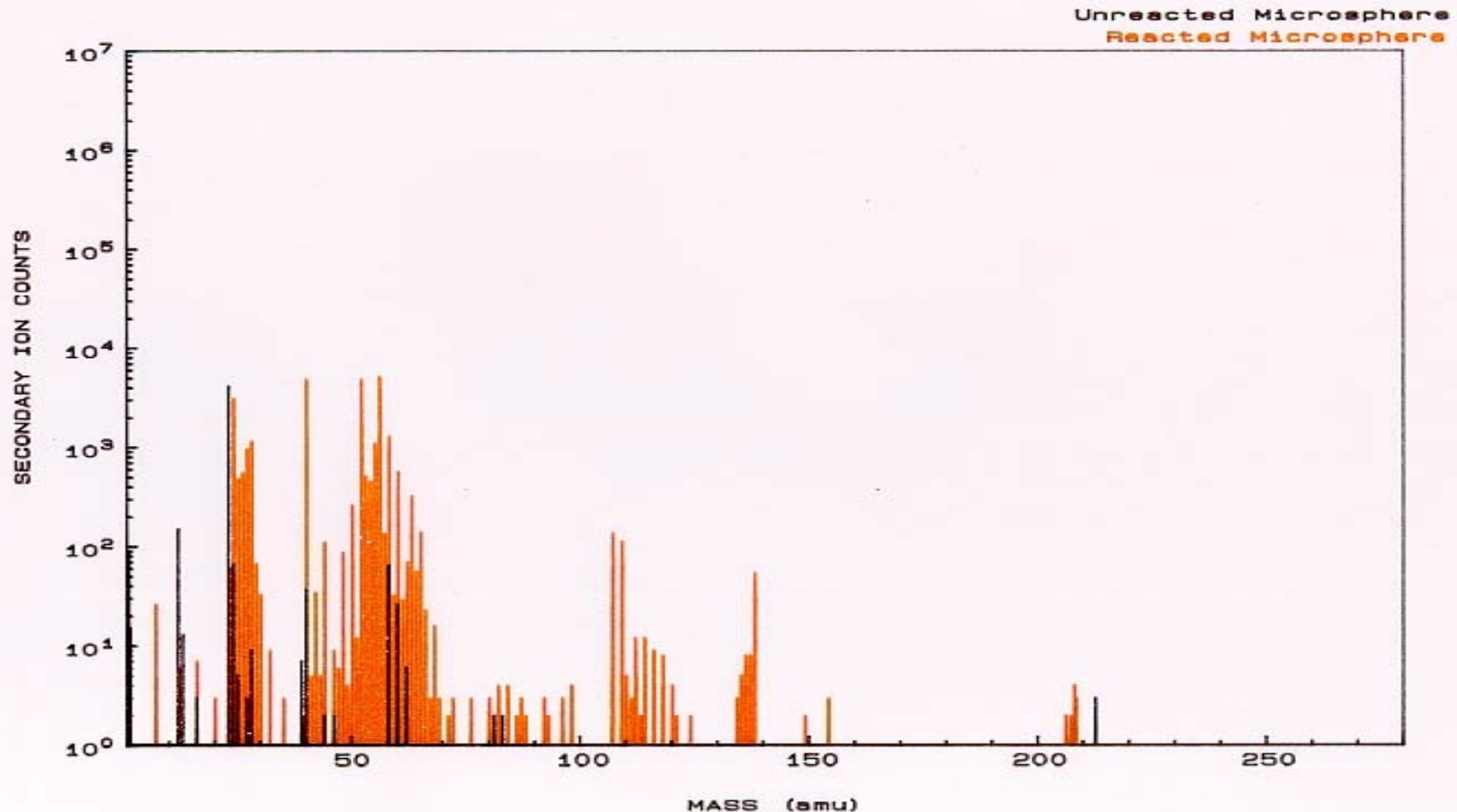
- Initial runs done in low resolution.
- conditions (off-set voltage, entrance/exit slits, field aperture, energy slit) optimized to minimize interferences.
- Isotopes of interest with possible interference then selected for high resolution.
- Error analysis considers interference effects, fractionalization, non-uniformity, small sample numbers.

# Operating Characteristics of Dual Focusing SIMS (CAMECA IMS 5f)

primary ions: 10 to 40 $\mu\text{m}$ $\text{O}_2^+$ at 14.5 keV
primary ion raster size: 125x125 $\mu\text{m}^2$
primary ion current: 10 nA (25-100nA occasionally used)
mass resolution ( $\frac{M}{\Delta M}$ ): 300 low and 5000 high resolution mode
secondary ion polarity: positive
field aperture: 400 $\mu\text{m}$ ; contrast diaphragm aperture: 150 $\mu\text{m}$
sample chamber pressure: $\leq 5 \times 10^{-10}$ Torr

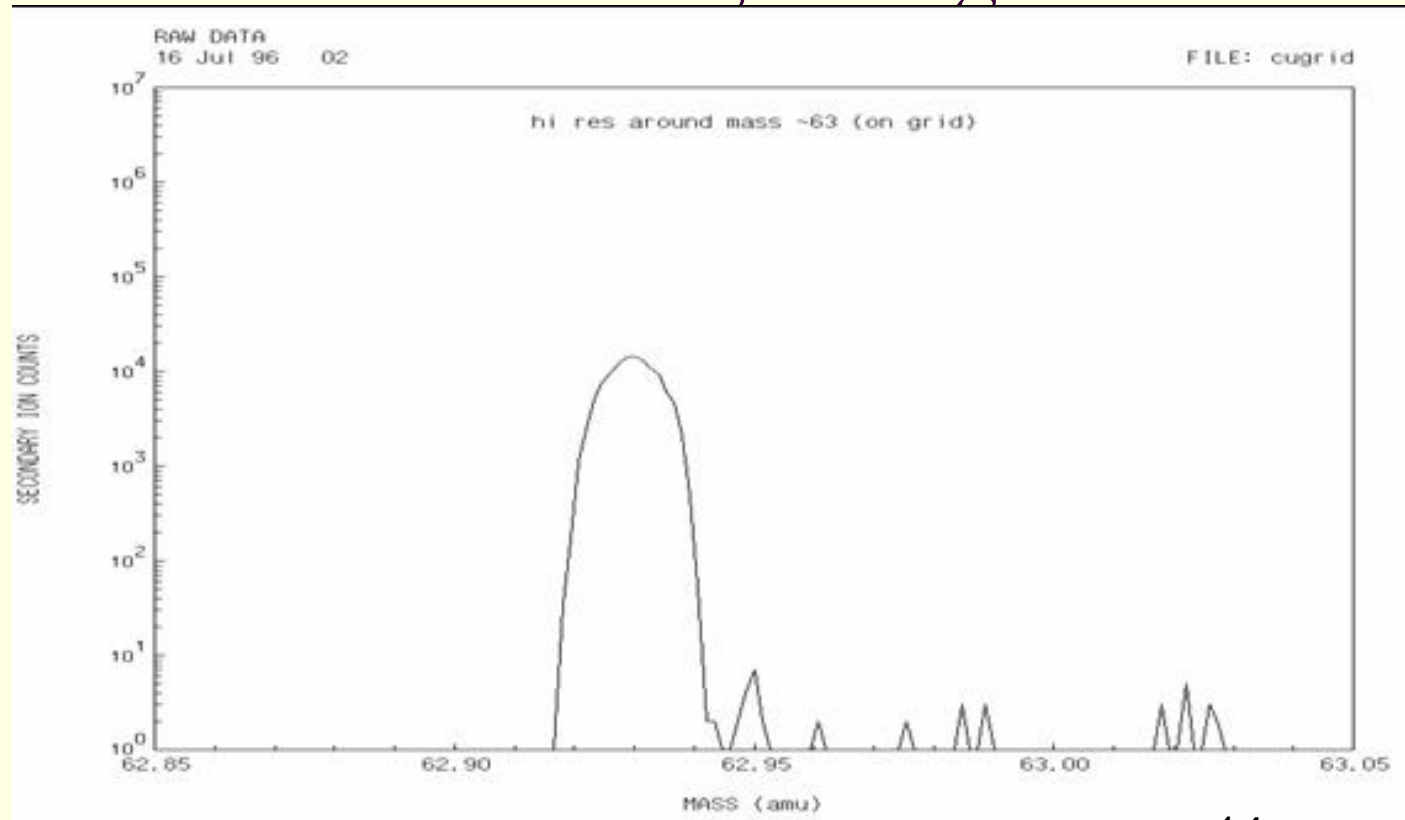
*Table 2.2. Experimental conditions for SIMS analysis.*

# Quantification of Isotopes by Combined SIMS & NAA



Mass Spectrum of a sample, indicates relative concentrations of species. Compare spectrum before and after electrolysis.

High-Resolution Mass Spectrum for  $^{63}\text{Cu}$   
Isotope Identification. The Mass Range  
Analyzed is 62.85 to 63.05 amu, with a  
Total of 150 Channels, Going of  $\sim 4625$ .



# Parameters for NAA Runs

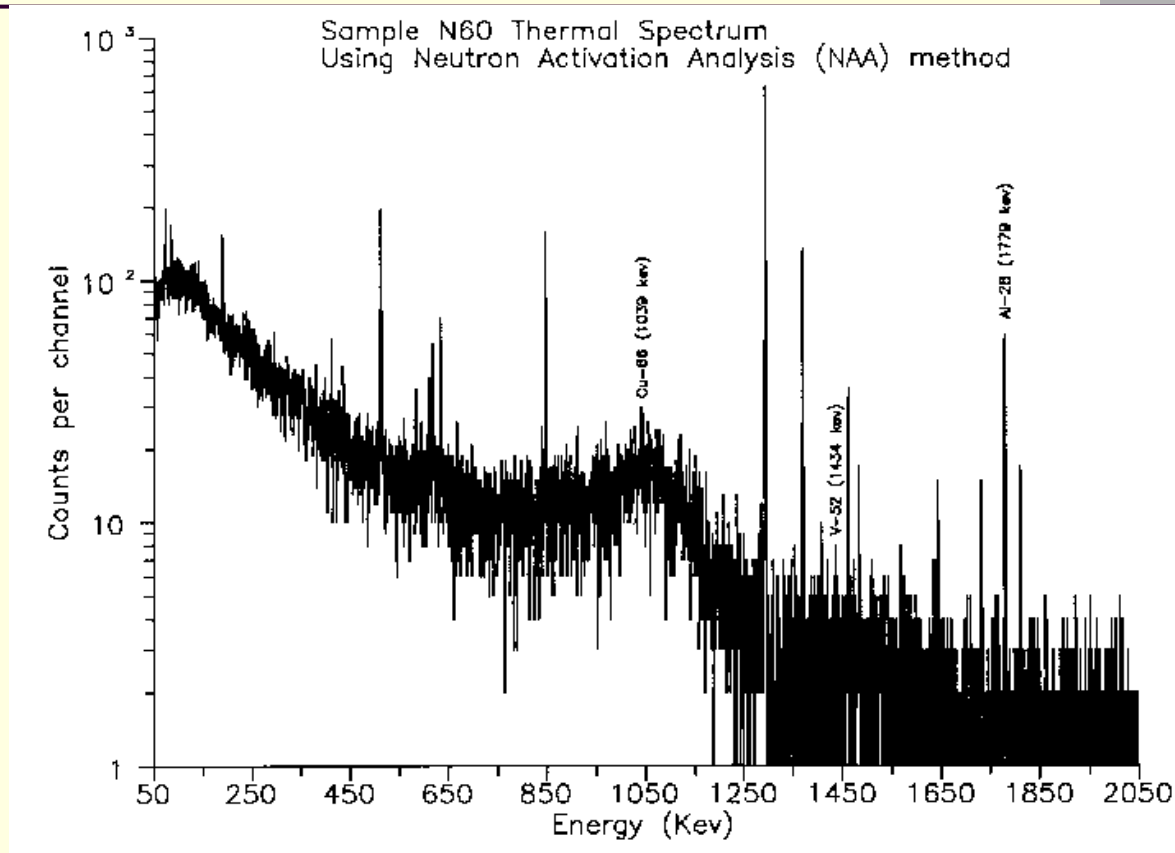
Method	Irradiation facility (flux, n cm <sup>-2</sup> s <sup>-1</sup> )	Analytical Procedure		
		Irradiation time	Decay time	Counting time
Thermal short-lived	PS (3.7E+12)	10 - 300 sec.	5 - 20 min.	10 - 20 min.
Epithermal medium- lived	CLNAT (2.1E+11)	2 - 8 hrs.	2 - 5 days.	1 - 10 hrs.
Thermal long-lived	LS (3.4E+12)	2 - 6 hrs.	15 - 35 hrs.	3 - 6 hrs.

# NAA Detection System and Analysis

- The gamma-ray detector system had: a liquid N<sub>2</sub> cooled high purity germanium (HPGe) crystal detector with an 18% relative efficiency (1.9-keV resolution for the 1332-keV photopeak of <sup>60</sup>Co); A large NaI(Tl) crystal ring detector outside the main detector; An ORTEC ADCAM PC-based multichannel analyzer.
- Compton suppression was used to further minimize the background.
- A reference standard method was used to determine the comparative method for measuring the concentration of the element(s). This used simultaneous irradiation and -counting of a prepared NIST sample (one standard for each element to be estimated) along with the test sample.
- The spectrum data was processed using the Neutron Activation Data Analysis (NADA) code. The output included concentration values in %, ppm, g or ppb units and associated errors.
- Flux variations, high deadtime corrections, counting geometry, spectral and nuclear interference, as well as uranium fission interference were accounted for in analysis



# Typical NAA Spectrum



## NAA Result

Sample ID	ppm
Ag (ppm)	125.4
Al (ppm)	11.2
Cu (ppm)	27.0
V (ppm)	0.1
Cr (ppm)	2.9
Ni (ppm)	1821.0
Fe (ppm)	217.2
Zn (ppm)	15.4
Co (ppm)	0.6

Gamma spectrum with sample chart of concentrations. The spectrum of gamma-rays is used to identify and quantify the element that emitted it, using a reference sample in the same run.

# NAA Results Before and After Run Shows Large Increase in Nine Elements Selected

Element	Concentration (ppm)	Error (ppm)	Detection Limit (DL) (ppm)
Ag	1.88	0.14	0.02
Al	40.66	2.75	1.60
Cu	< DL		24.62
V	< DL		0.19

*Table 5.7(a). NAA result of microspheres from batch #prior to run #15.*

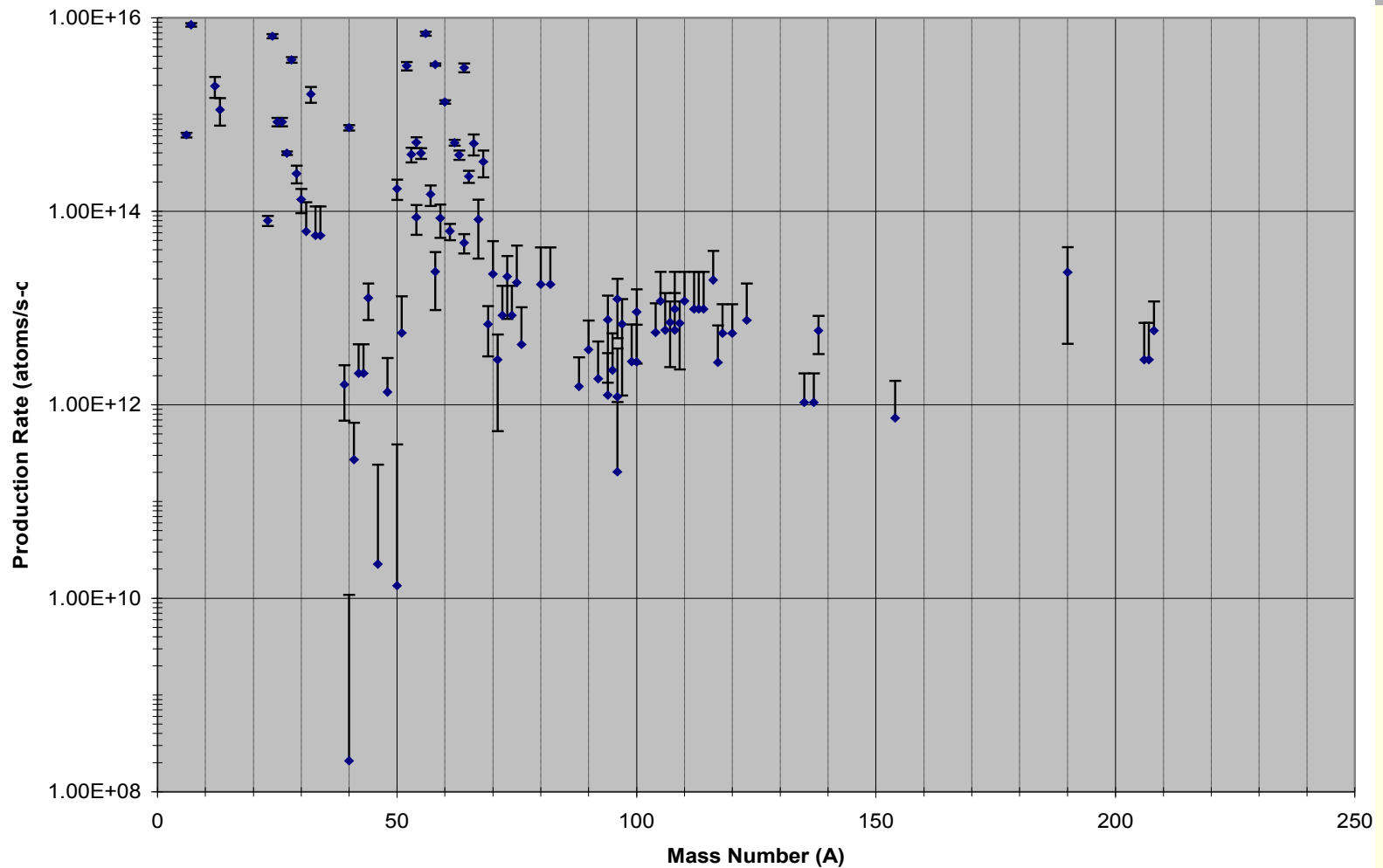
Element	Concentration (ppm)	Error (ppm)	Detection Limit (ppm)
Ag	5.53	0.38	0.47
Al	39.17	3.24	4.21
Cu	141.54	26.79	79.10
V	1.02	0.15	0.32
Fe	1528.83	59.93	135.47
Cr	722.79	7.63	3.81
Co	18.23	0.29	0.21
Ni	1123.88	18.46	24.99

*Table 5.7(b). NAA result of microspheres from batch #15.1.1 after run #15.*

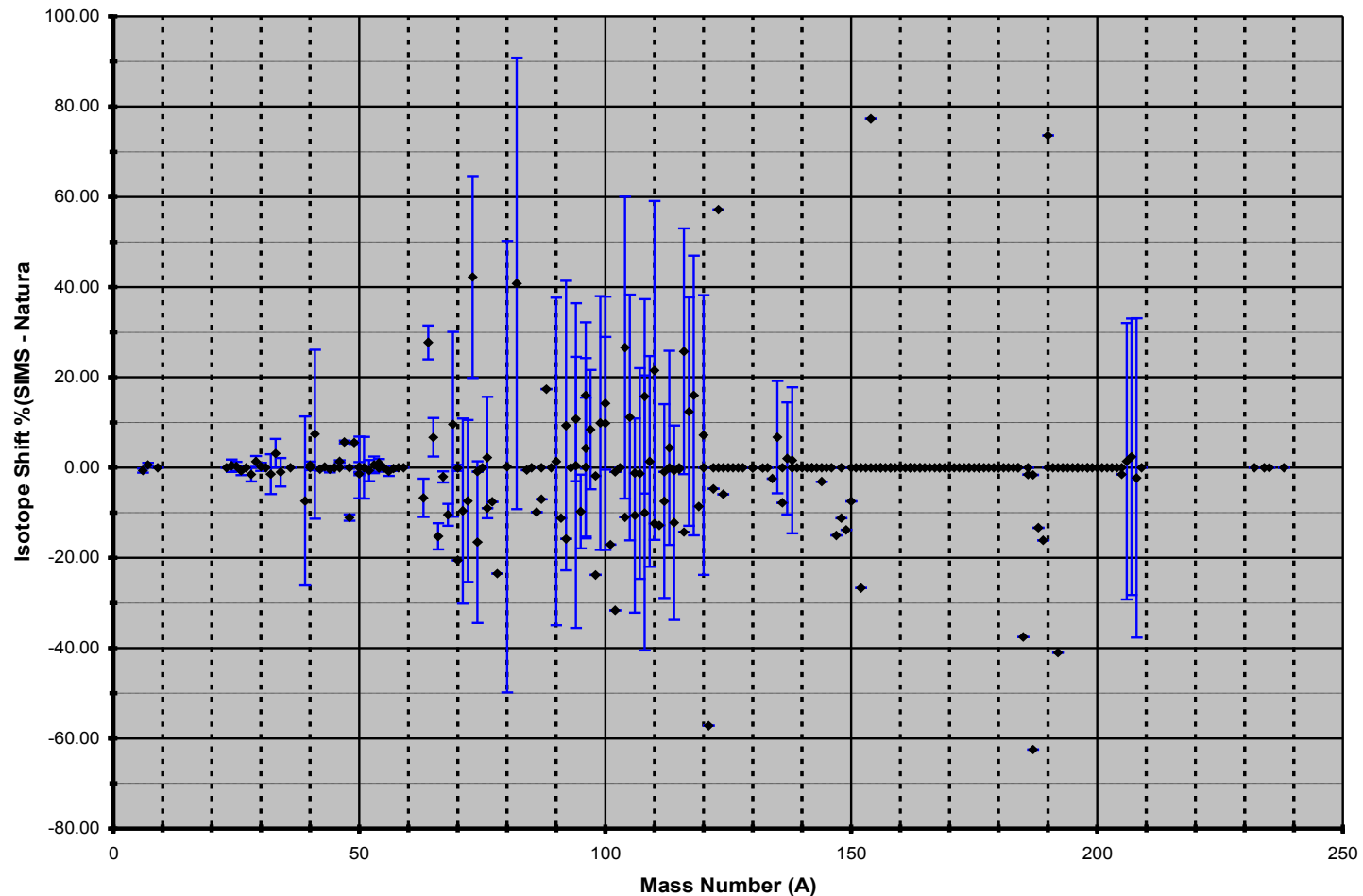
# Results

- Large increase in number of isotopes found after a run.
- Four regions (“peaks”) of mass number have higher concentrations.
- Concentrations appear to be much larger than possible due to impurities in cell.
- Concentrations divided by run time defined as reaction production rate.
- Isotopes in 39 elements show significant deviations from natural abundance.

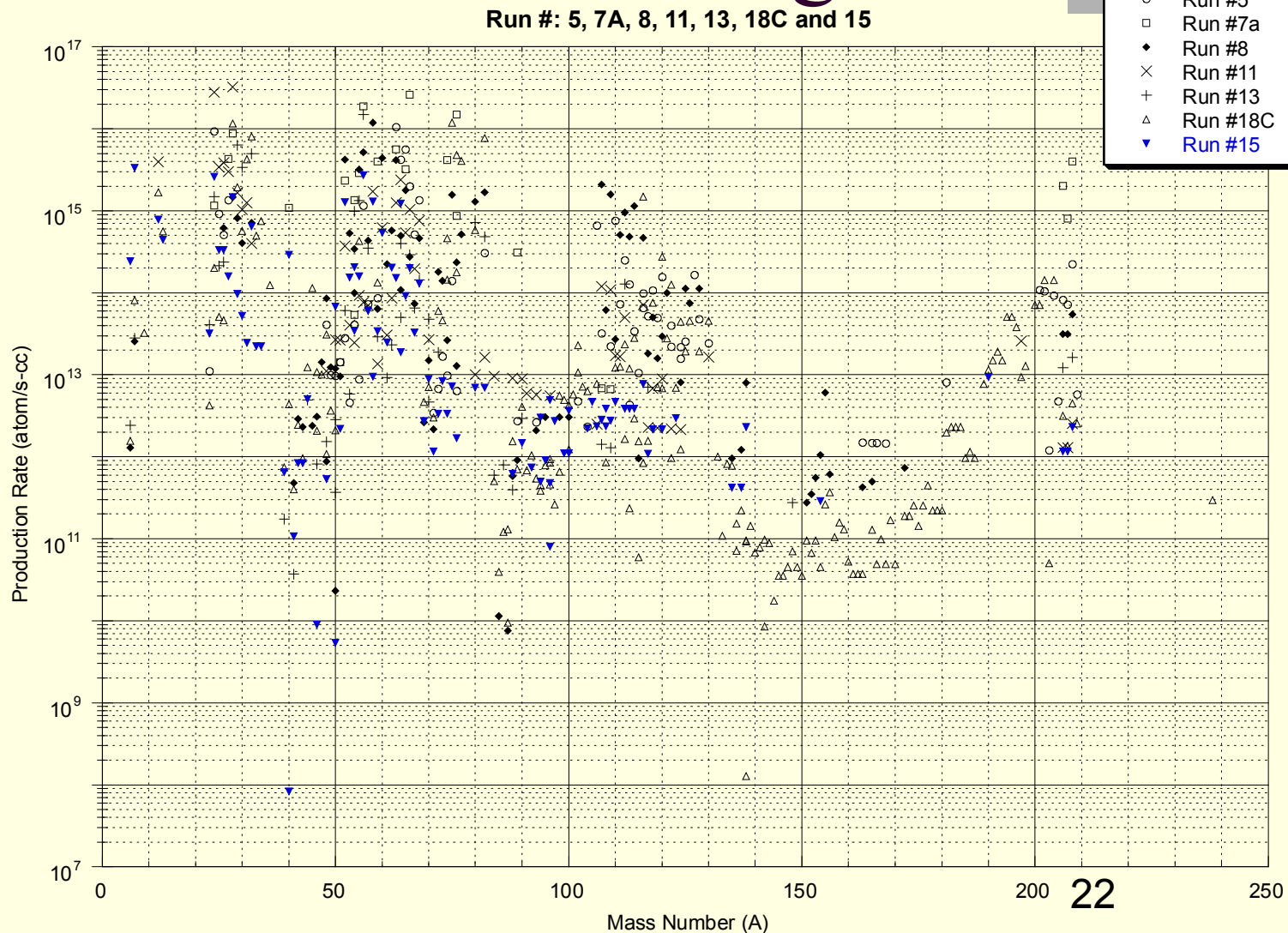
# Isotope Production Rates Show Large Yields of Key Elements and 4 “peak” Pattern



# 39 Elements Show Significant Isotope Shifts from Natural Abundance



# Comparison of Ti Run with Prior Data for Other Coatings Such as Ni



# Conclusions and relation to Rossi

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- To summarize, this research developed a unique SIMS-NAA analysis technique for studies of isotopes in thin films after undergoing electrolysis in a packed bed cell.
- This technique combines the broad coverage of elements with SIMS and the absolute precision capability of NAA.
- This technique should be applicable to a broad range of analysis problems of interest.
- I would suggest that this technique be applied to the Rossi cell
- A key issue – are these product & associated reactions responsible for the excess heat? As shown in later slides, the answer seems to be that these reactions are a major contributor.

- Ideal smoothed coated films not as good as “rough” ones. Implied local defects played a role. Reaction products highly concentrated near interfaces, perhaps due to anchoring of dislocations there.

## Other lessons learned



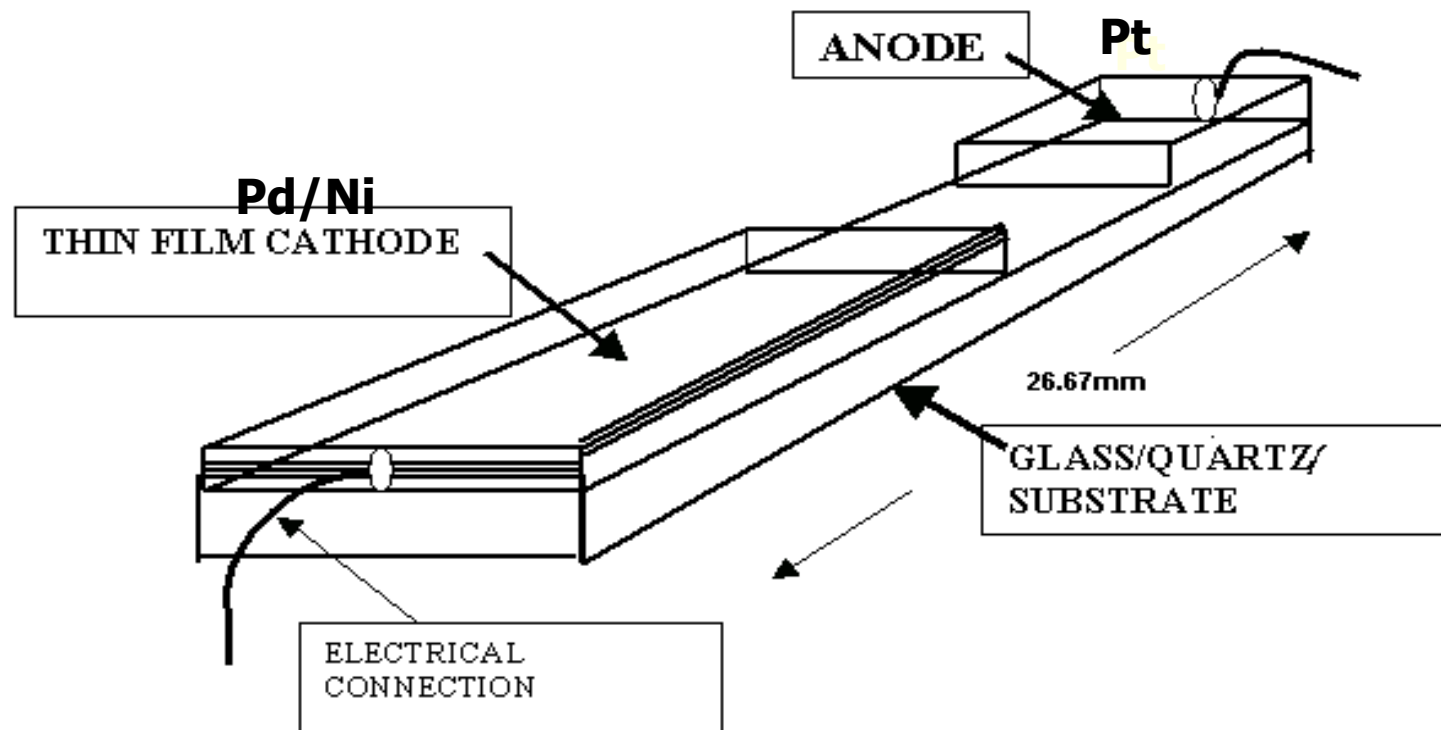
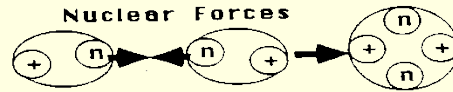
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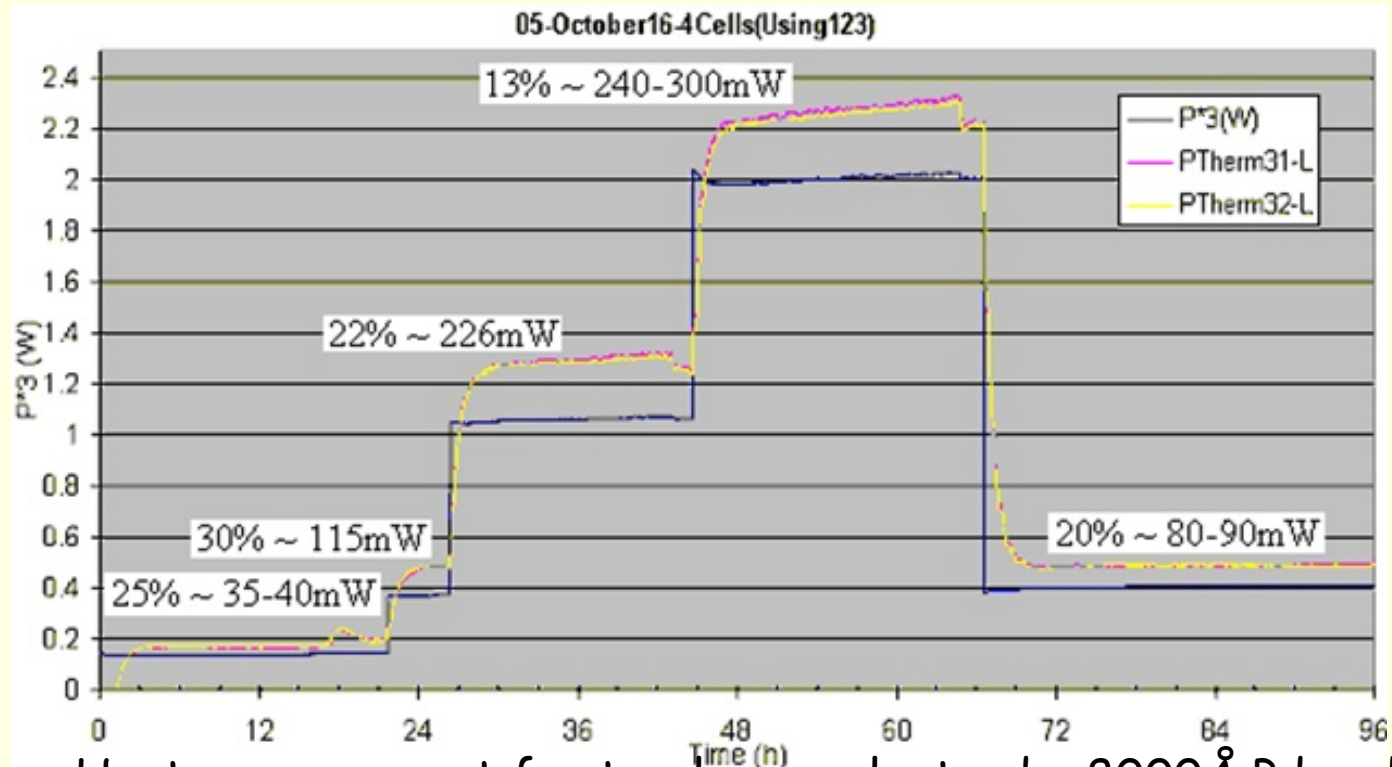
# SEL Theory Lead to Multilayer Thin-film electrodes- went to flat plates vs. beads to obtain better control over manufacturing film & defects

## ■ Concept



Multilayer thin-film electrode design with alternating layers of Pd & Ni.  
Planar A-K structure used to maximize H<sub>2</sub> concentration via electrodiffusion

# Results #1 -- Calorimetry Shows During Electrolysis Thin-Film Electrodes Produce Significant Excess Heat

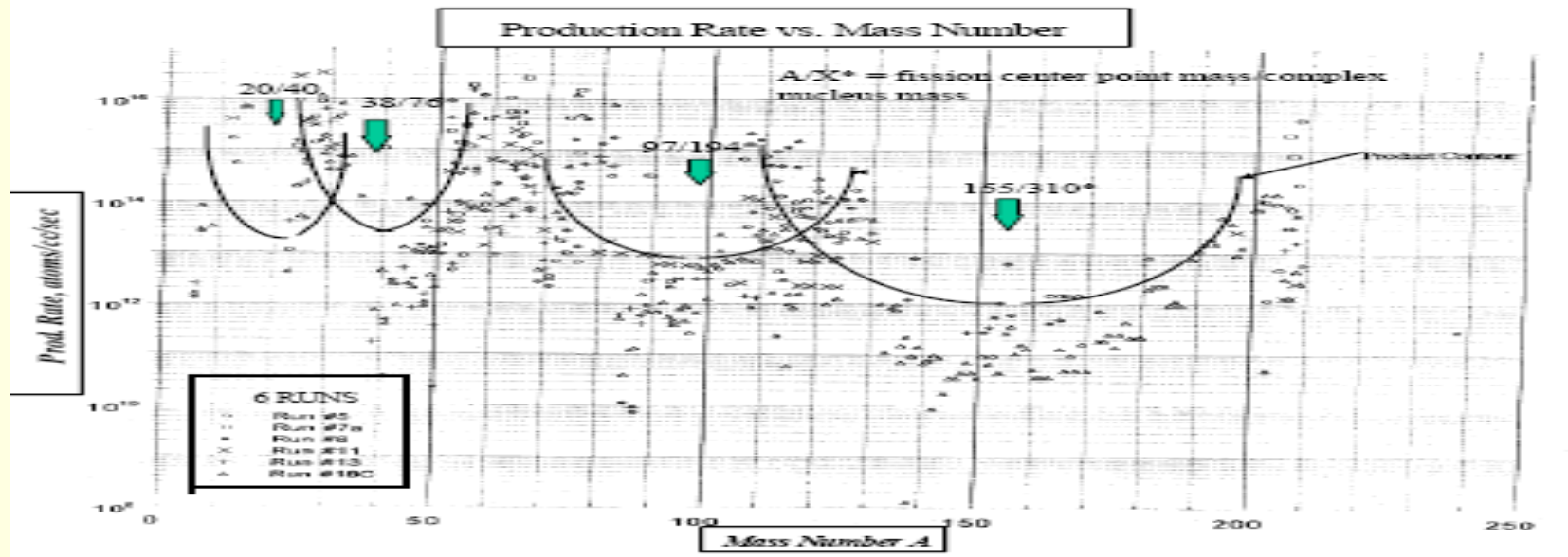


Heat measurement for two layers electrode: 8000Å Pd and 1000Å Ni on Alumina.

$P_{therm}$ : Measured Heat power;

$P^*=I(U-U_0)$ : Input electrical Power

# Results #2 -- Transmutation Products



## Reaction Product Yield vs. Mass Curve

### D-D Reactions

		hot fusion	% branching "P-F" type
D-D	$T + p$	50	< 0.1
	$\text{He-3} + n$	50	< $10^{-6}$
	$\text{He-4} + \text{gamma}$	< $10^{-5}$	99+

### Transmutations

proton + metal  $\rightarrow$  products or "fission" product

# Computation of excess power from reaction product measurements gives order of magnitude agreement with measurement.

$$\left[ \sum_{RPi} (RP * BE/n) - \sum_{\substack{\text{metal atom,} \\ p \text{ burned}}} (fuel * BE/n) \right] / \text{run time} = P_{\text{out}}$$

$$\Xi W_{\text{excess}}$$

Computation of Excess Power from measured reaction products and binding energies where:  
 RP = reaction product yield or atoms of product formed nuclei  
 BE /n= Binding energy per nucleon for RP or fuel  
 fuel = metal nuclei + protons reacted (from nucleon balance)  
 p = proton

Run Number	Excess Power (W)	
	Calculated	Measured
#7	1.9 ±0.6	4.0 ±0.8
#8	0.5 ±0.2	0.5 ±0.4
#18	0.7 ±0.3	0.6 ±0.4

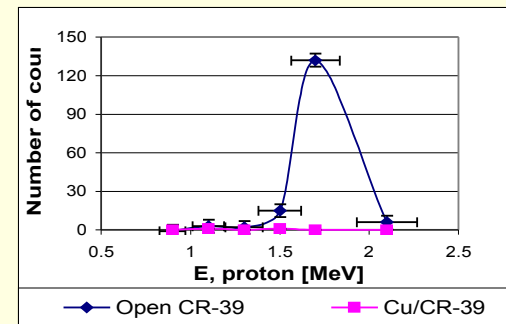
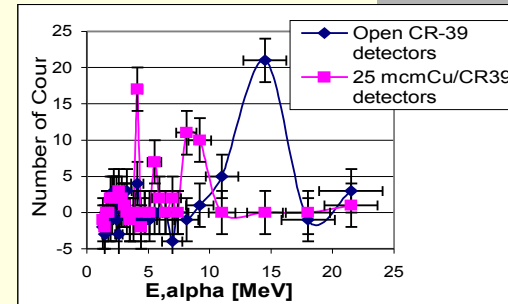
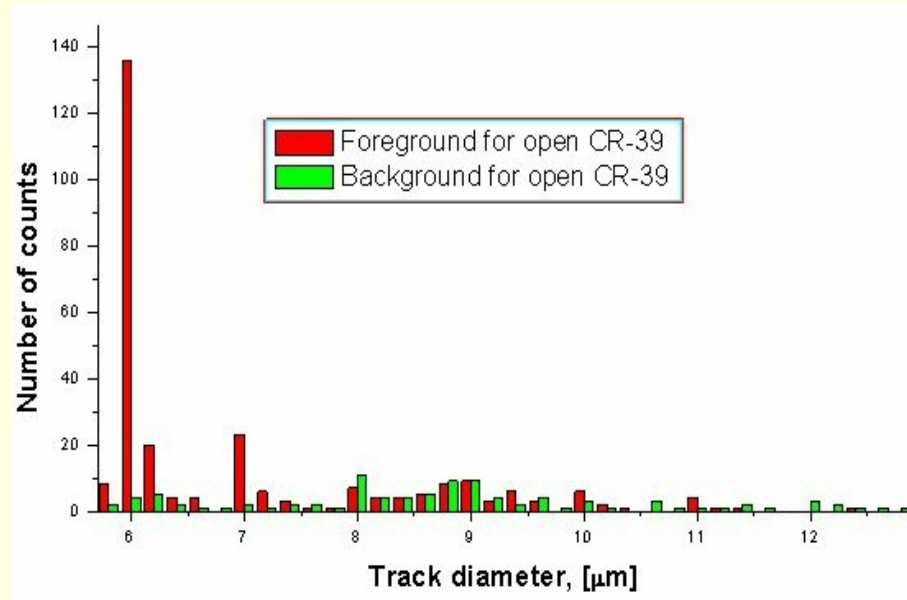
Equation

Results from Energy Balance Calculations for Three earlier Thin-Film experiments.

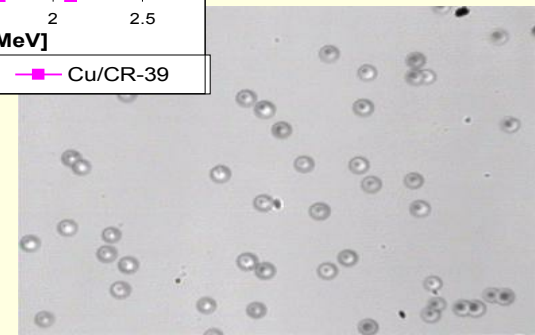
**All experiments used Li2SO4 in H2O for the electrolyte and thin-film Ni coated cathodes.**

# Results #3 -- MeV charged-particles

## Alpha-Particles and Protons



High-energy charged particles After background  
1.5 - 1.7 MeV protons and 11-16 subtracting  
MeV alphas.



**Tracks in CR-39 from 12.0 MeV  $\alpha$ -particles; image area  $S = 0.2 \times 0.2$  mm, (X 700)**

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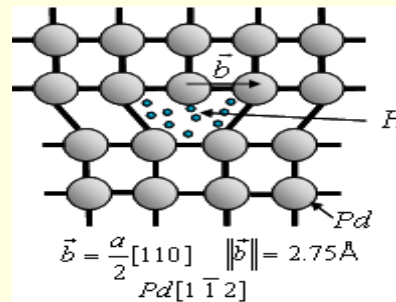
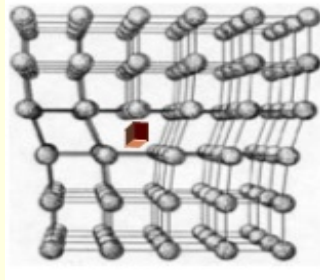
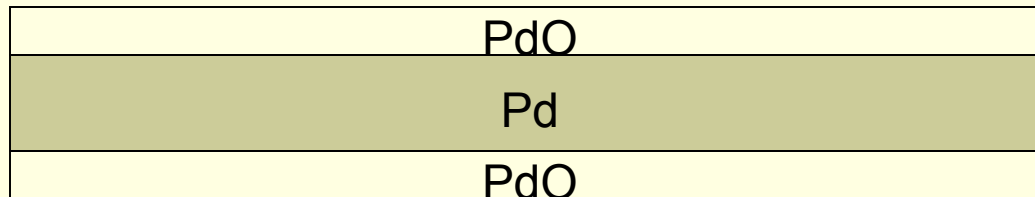
# Comment -

Propose search for charged particle and soft x-ray emission from Rossi

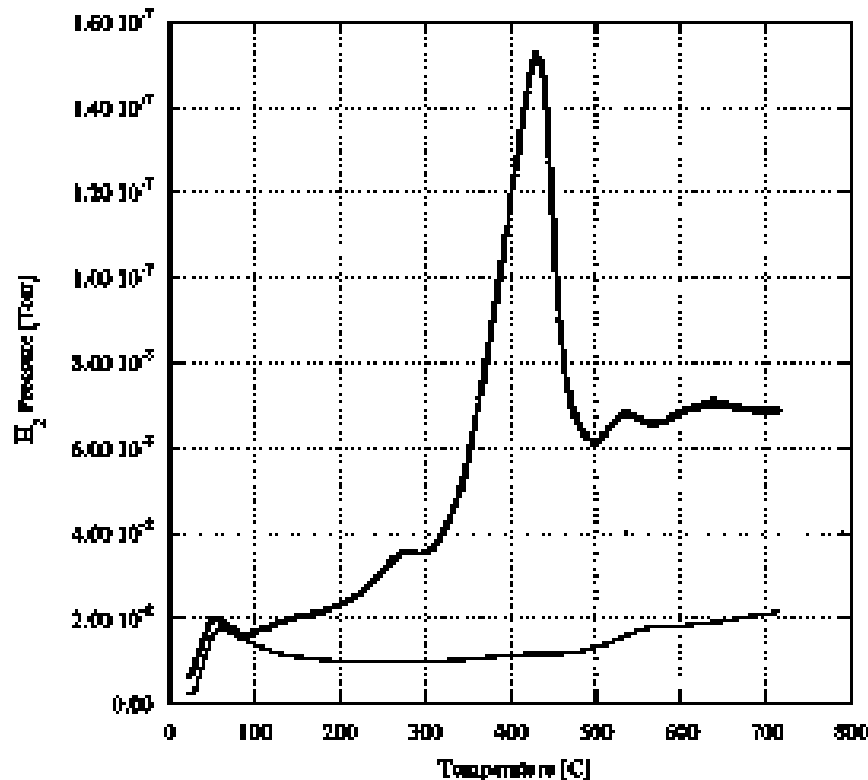


# Our Recent Dislocation-Loop-Cluster Studies

- Pd thin foil – 12  $\mu\text{m}$
- Loading and unloading deuterium/hydrogen was done by cyclically cathodizing and anodizing Pd foil ü dislocation loop and cluster formation



# Temperature Programmed Desorption (TPD) Experiment

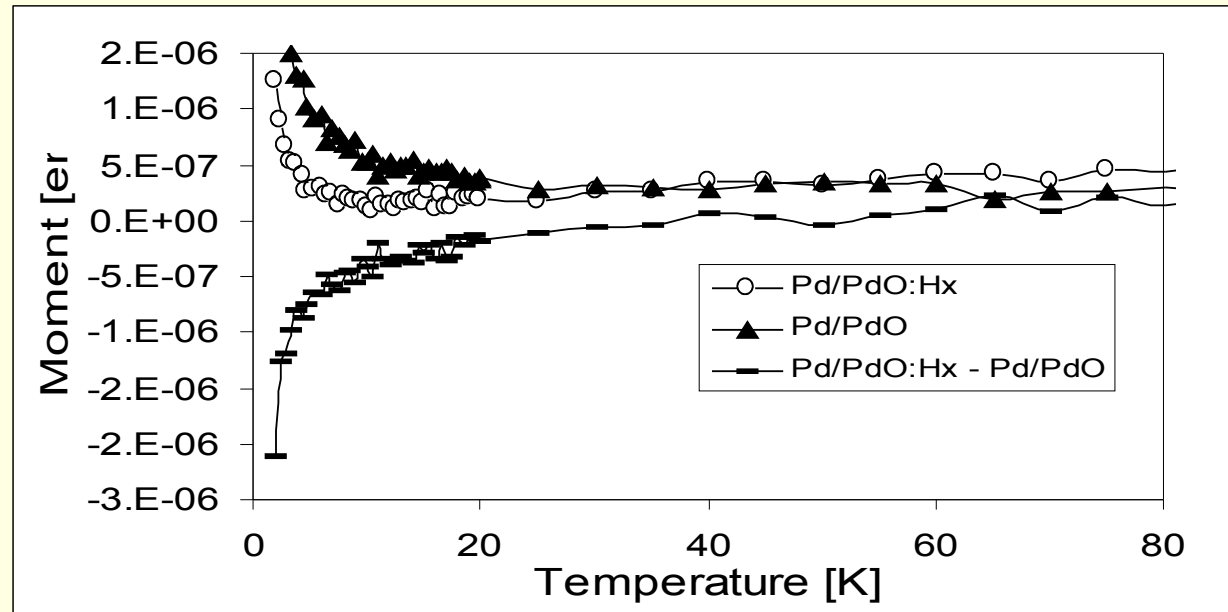


Binding Energy calculation –  
close to the binding energy  
between hydrogen and  
dislocations

$$\epsilon_H = k_B \frac{T_2 T_1}{(T_2 - T_1)} \ln(P_2 / P_1) = 0.65 eV$$

After the loading foil was annealed under 300 oC for 2 hr, the temperature was ramped from 20 oC to 800 oC at 9 oC /min.

# Experimental Magnetic Moment Measurements of Pd:H sample show superconducting state



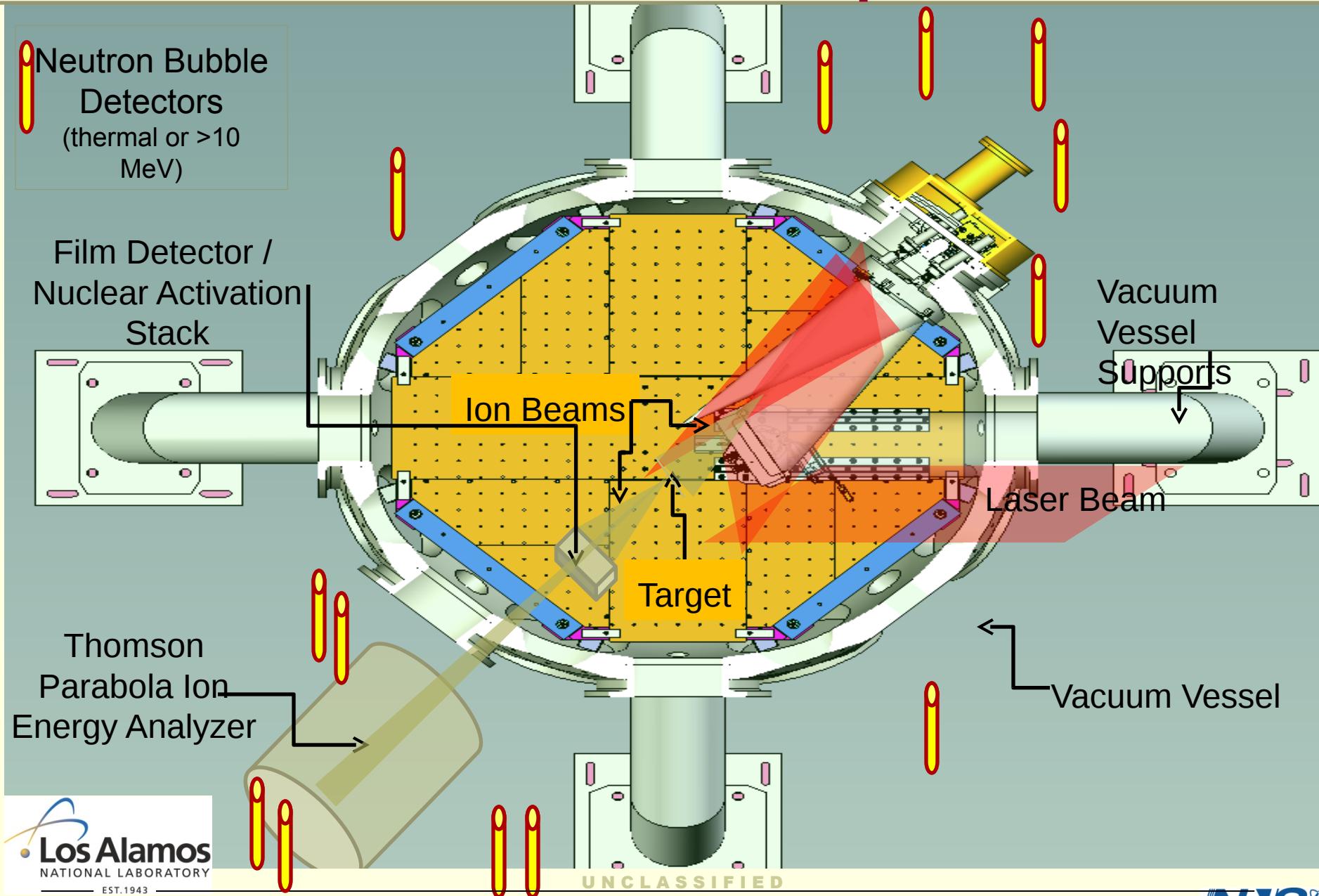
The magnetic moment of H<sub>2</sub>-cycled PdH<sub>x</sub> samples in the temperature range of 2 ≤ T < 50 K is significantly lower than M(T) for the original Pd/PdO.

A. Lipson, B.I. Heuser, C. Castano, G.H. Miley, B. Lyakov & A. Mitin,  
**Physical Review B 72**, 212507/1-6 (2005):

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- We are funded to do experiments at LANL to study the extraction of MeV D<sup>+</sup> ions from these clusters using the TRIDENT petawatt

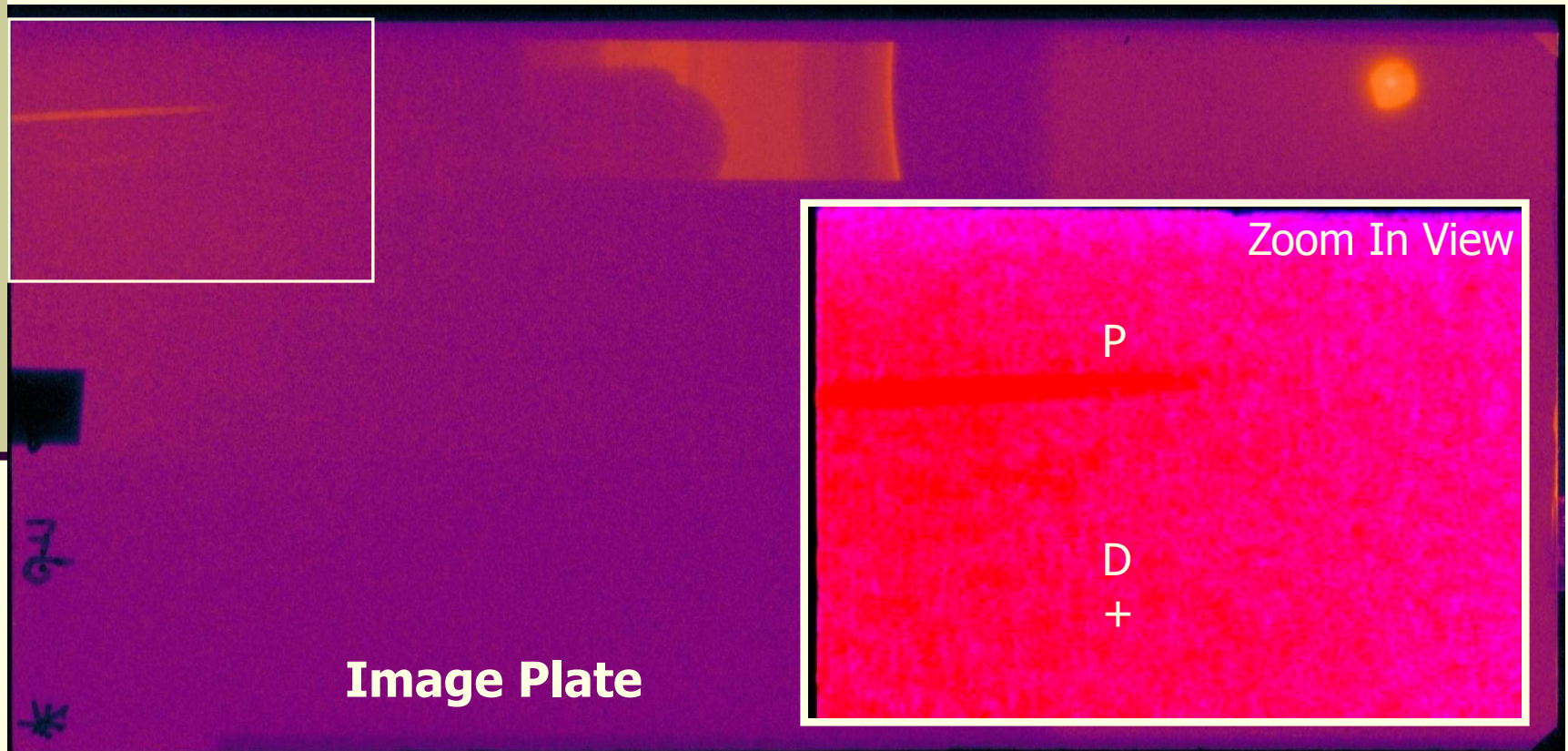
laser  
Another proof of clusters –  
petawatt laser beam extraction

# Deuteron Acceleration Experiment In LANL



# Ion Trace of PdD Separated by Thompson Parabola WITH Ti Filter

Laser Energy in 81.9 J out 67.1



# Comments –TRIDENT results

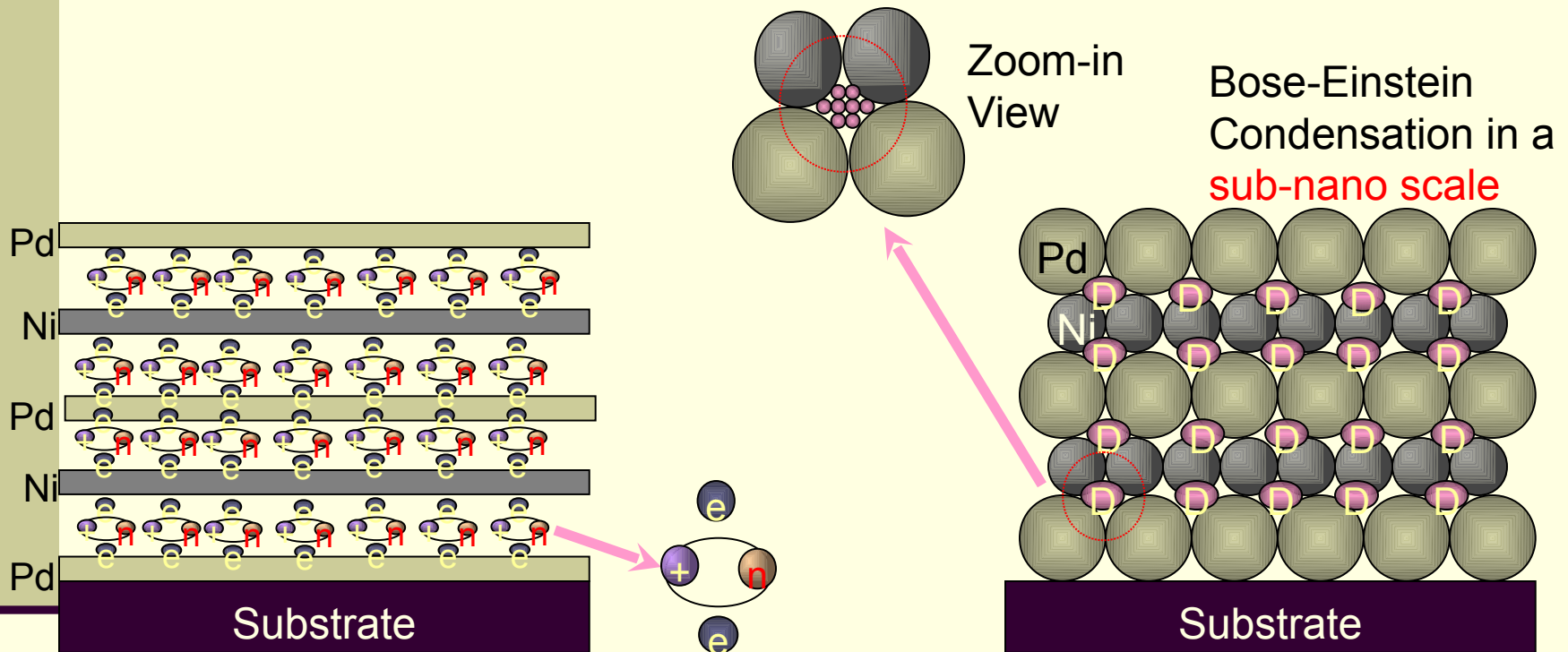
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- Demonstrate acceleration from clusters
- Flux and energy depressed, probably by impurity protons (and C?)
- Next experimental campaign
  - Continue to improved cluster packing fraction
  - Reduce contamination (p and C).
  - Obtain more insight from ongoing supporting simulation studies.

**Conclusion: High density  
deuterium cluster formation  
(Pseudo Bose-Einstein  
Condensation) at room  
temperature occurs and is  
fundamental as a way to  
create nuclear reactive sites  
for LENR**



# Theory



Yeong E. Kim, Theory of Bose-Einstein condensation mechanism for deuteron-induced nuclear reactions in micro/nano-scale metal grains and particles, Naturwissenschaften, 96(7):803-11 (2009)

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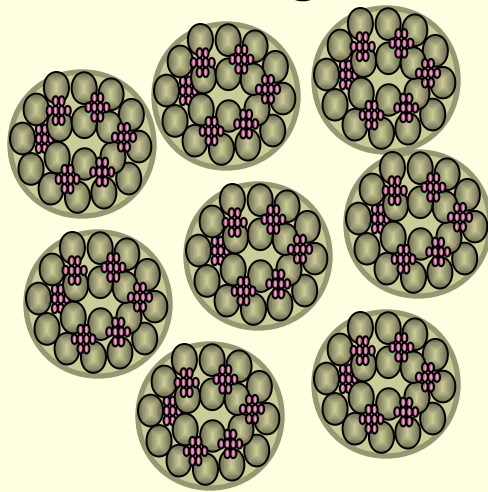
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Recent work is designed to extend the thin-film technique to nanoparticles.

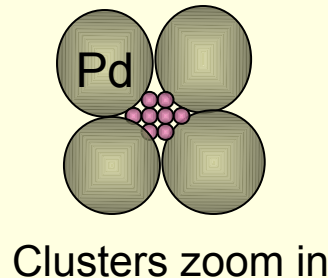
For applications this will allow high temperatures with gas loading – i.e. improved performance when energy conversion is integrated into the cell

# Cluster Formation in Nanomaterials

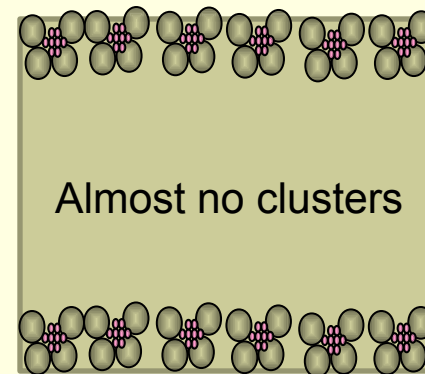
- Clusters mainly forms at the places that is close to the material surface.
- Nanomaterials have more surface area, thus have good ability to form abundant clusters



Nanoparticles



Clusters zoom in



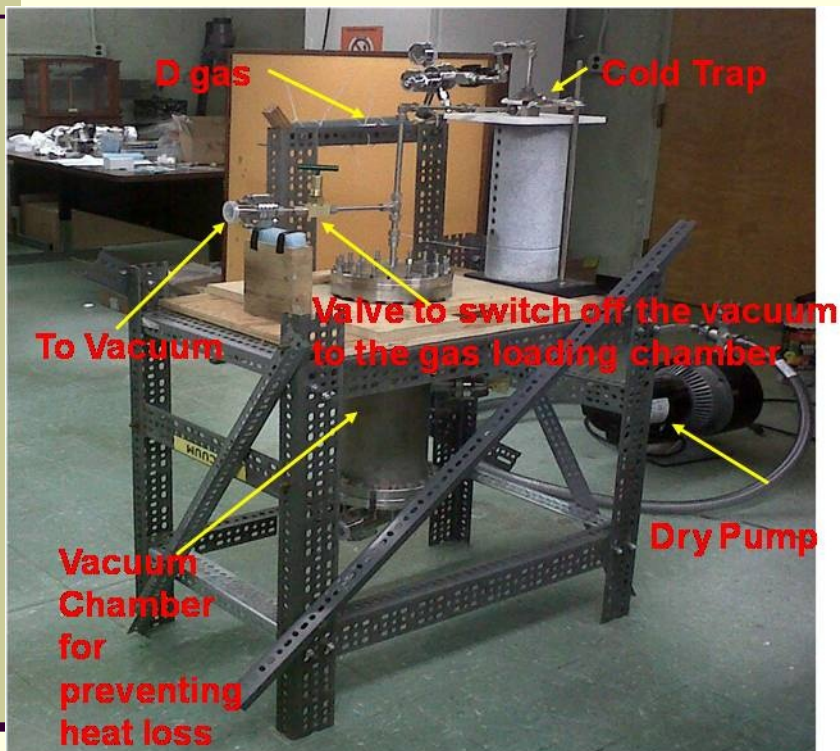
Bulk material

# Triggering The Reaction

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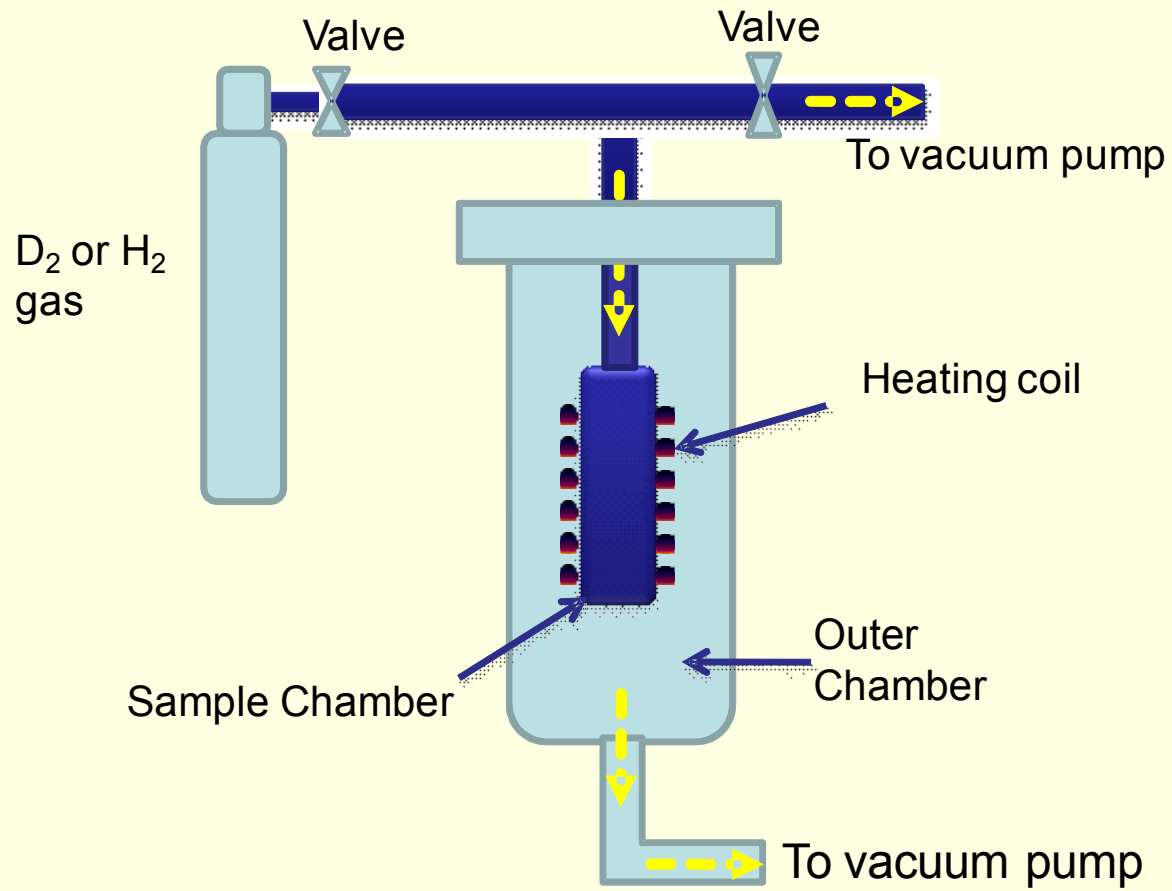
- Electrolysis (pulse or ramp)
- Gas loading (pulse pressure)
  - Smaller heat capacity
  - Higher temperature change as compared with an electrolysis system.
  - Without the constraint of being limited by the boiling temperature of the fluid
- Glow Discharge (bombardment)
- Low energy laser; ultrasound; em radiation,.....

# Our Gas Loading System



2.2cm inner diameter  
25cm<sup>3</sup> total volume

# Inside View



# Preliminary Excess Heat Measurement Using Our Gas Loading Calorimetry System

High purity (99.999%) D<sub>2</sub> gas at 60 psi

**20g ZrO<sub>2</sub>Pd<sub>35</sub> nano powder**

Gas loaded under room temperature and then unloaded.

exothermal energy from chemical reaction --- **690J**

Calculation: Energy =  $\Delta H \times MD_2$

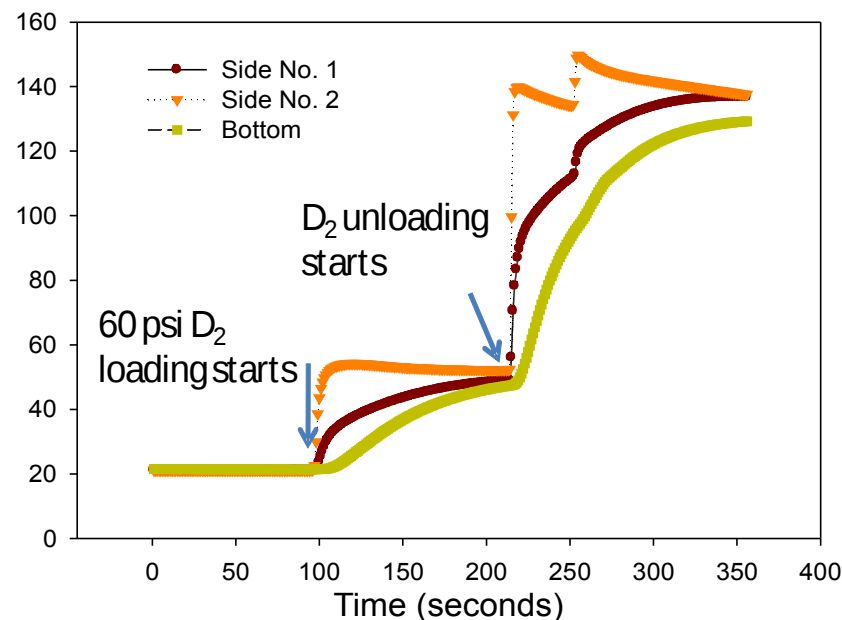
$\Delta H = -35,100\text{J}$  per mole of D<sub>2</sub> for the formation of PdD<sub>x</sub> for  $x < 0.6$ ;

MD<sub>2</sub> is the total moles of D<sub>2</sub> that combined with Pd

Actual measured energy -- **1479J**

Calculation: Energy =  $\Delta T(M_{\text{chamber}} S_{\text{chamber}} + M_{\text{powder}} S_{\text{powder}})$

$\Delta T$  is temperature change, M is mass, and S is the specific heat





The result show was from June –  
we have continued this work but I  
do not have slides to show of this  
work in progress

Most effort has been to develop improved nanoparticles by  
comparing and down selecting a series of triple alloys.

# Summary – gas loading

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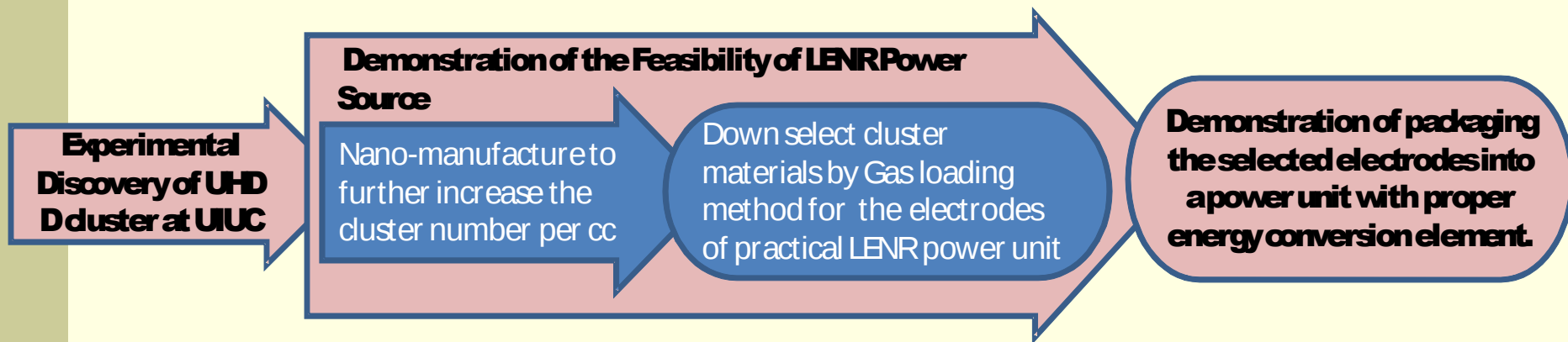
- Experimental evidence confirms cluster formation in dislocation loops.
- Methods to fabricate high loop density under study.
- Further experiments should consider nanomaterials of different size and composition

# Outline

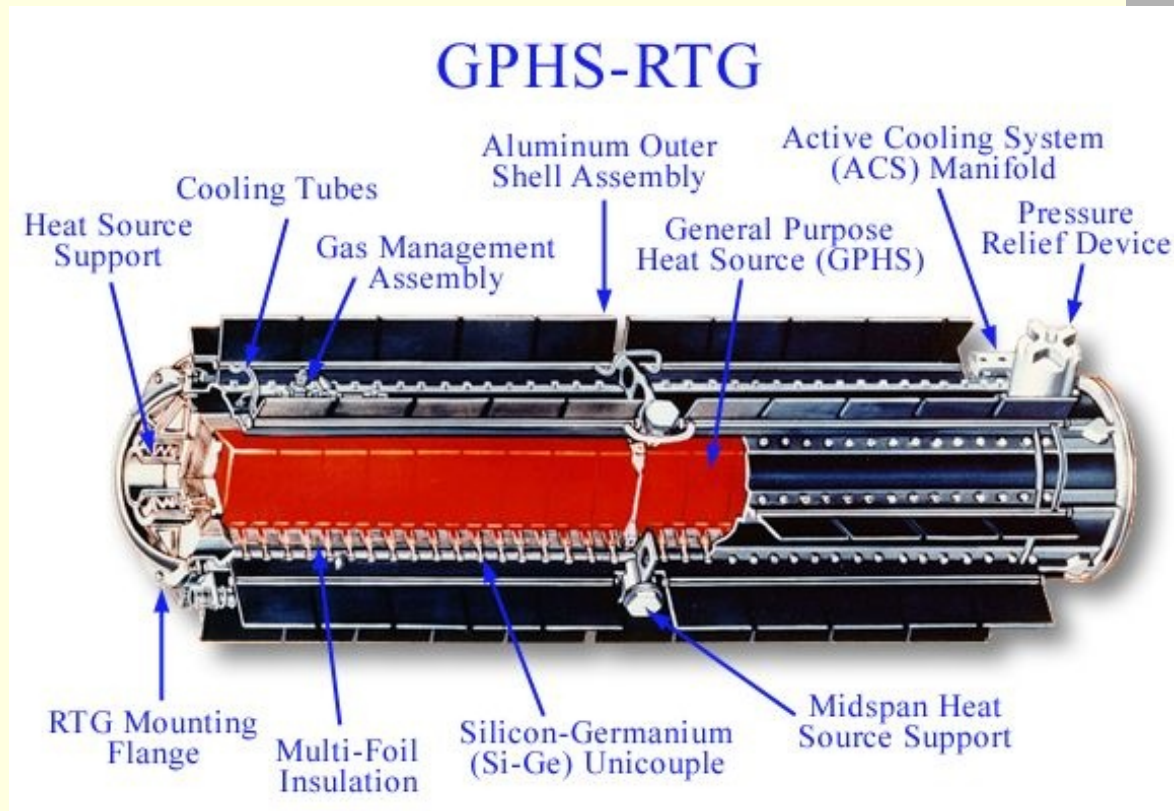
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# Road Map to a Prototype LENR Unit Development



The LENR power cell is well suited for use as a “New Type RTG” with the LENR cell replacing the PU238



Drawing of an GPHS-RTG that are used for Galileo, Ulysses, Cassini-Huygens and New Horizons space probes.  
source:<http://saturn.jpl.nasa.gov/spacecraft/safety.cfm>

# Many issues remain

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- What is the energy producing reaction and can it be optimized?
- Alternate metals (reduce costs, improve operation, etc.
- Alternate gaseous fuel? H<sub>2</sub>, D<sub>2</sub>, Tritium, D-T, etc?
- Are there any radioactive products?
- Any emissions? Soft x-rays, charged particles, gammas?
- Lifetime issues – radiation damage to the electrode materials?  
Effect of reaction production structure and also on stopping later reactions?
- Burn up of fuel? Burn up of fuel in local sites?
- Is there any direct energy conversion possibility?
- If heat, what is the optimum temperate-conversion method.
- Control methods?
- .....

# Acknowledgment

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- This work is supported by the New York Community Trust and NPL Associate Inc.
- Recent experimental work was under the assistance of Monish Singh, Erik Ziehm, Chi Gyun Kim, Ittinop Dumnernchanvanit, and Seth Hartman.

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