SMALL POWER CELLS BASED ON LOW ENERGY NUCLEAR REACTION (LENR) - A NEW TYPE OF "GREEN" NUCLEAR ENERGY

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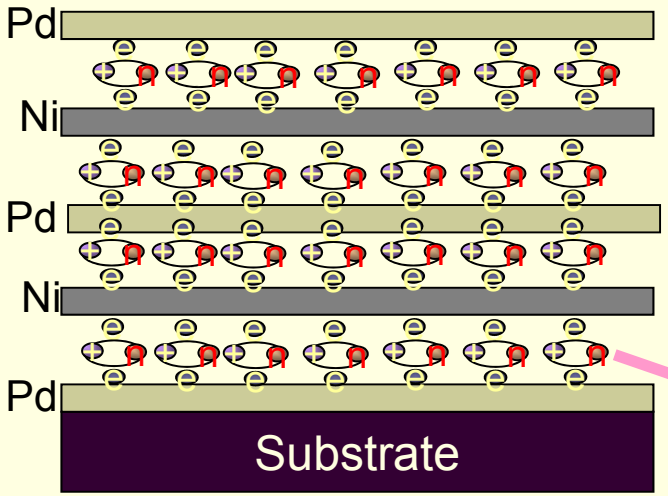
Outline

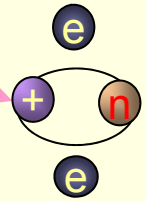
- The theories and corresponding observations of high density hydrogen/deuterium clusters
  - Previous Swimming Electron Layer (SEL) theory and related experimental results
  - Current dislocation theory -- Ultra High Density Deuterium Cluster
- Possible triggering method of nuclear reactions in these high density clusters
- Preliminary gas loading calorimetry experiment at UIUC
- Road Map and Future goal of the LENR study

SEL Theory

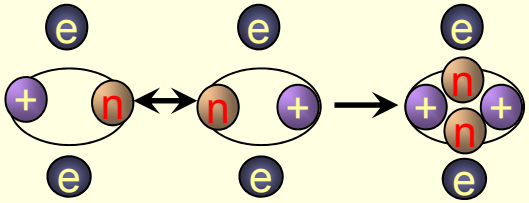


Swimming Electron Layer (SEL) Theory

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

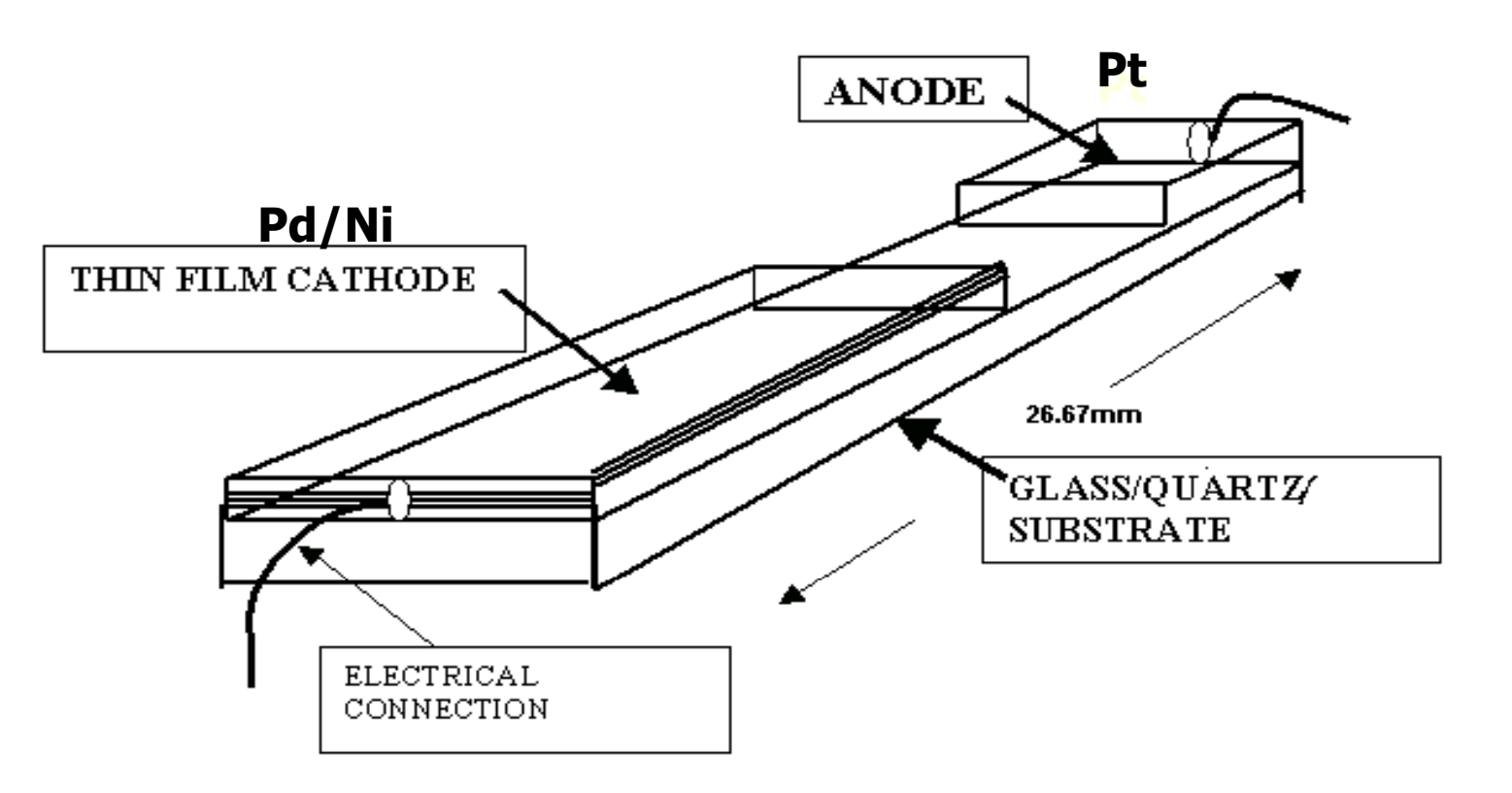


Zoom-in View



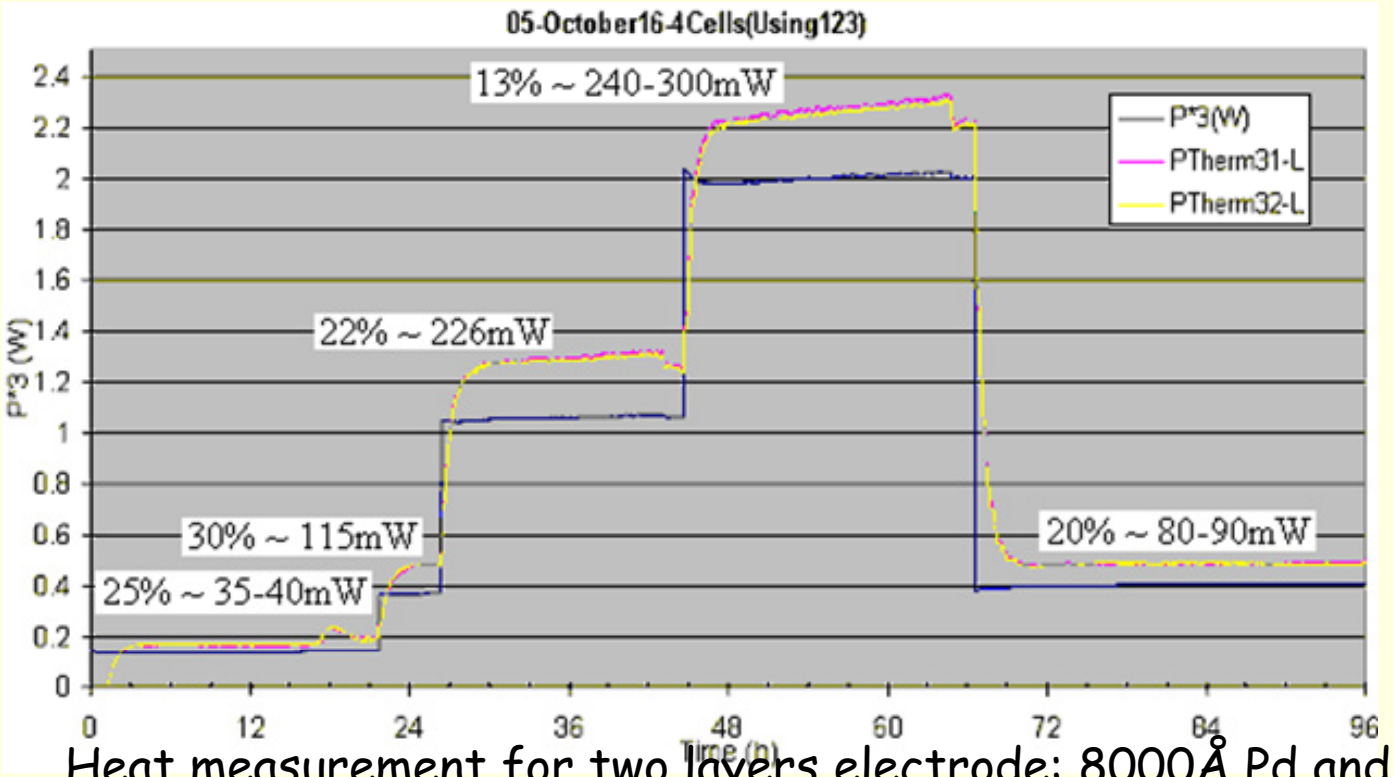
SEL Theory Lead to Multilayer Thin-film electrodes

- Concept



Multilayer thin-film electrode design with alternating layers of Pd & Ni

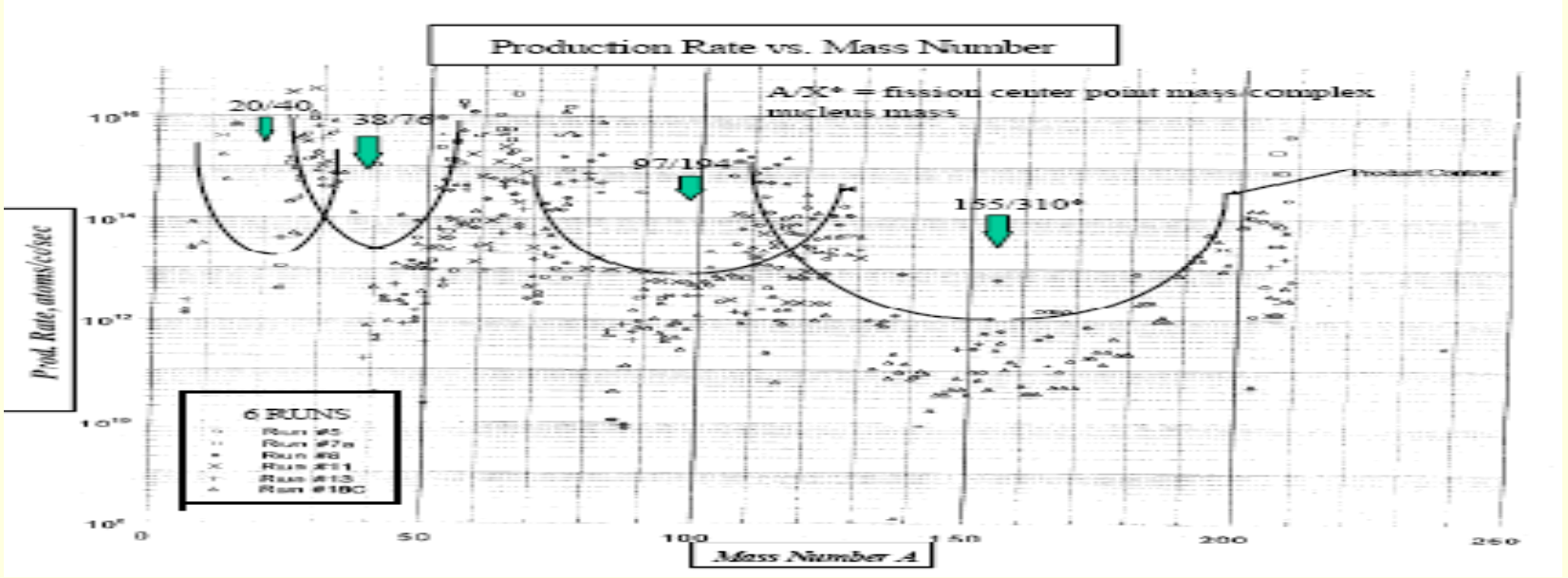
Results #1 -- Calorimetry Shows During Electrolysis Thin-Film Electrodes Produce Significant Excess Heat



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

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

Transmutations

proton + metal → products or "fission" product

Computation of excess power from reaction product measurements

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

$$\Xi\ W_{excess}$$

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

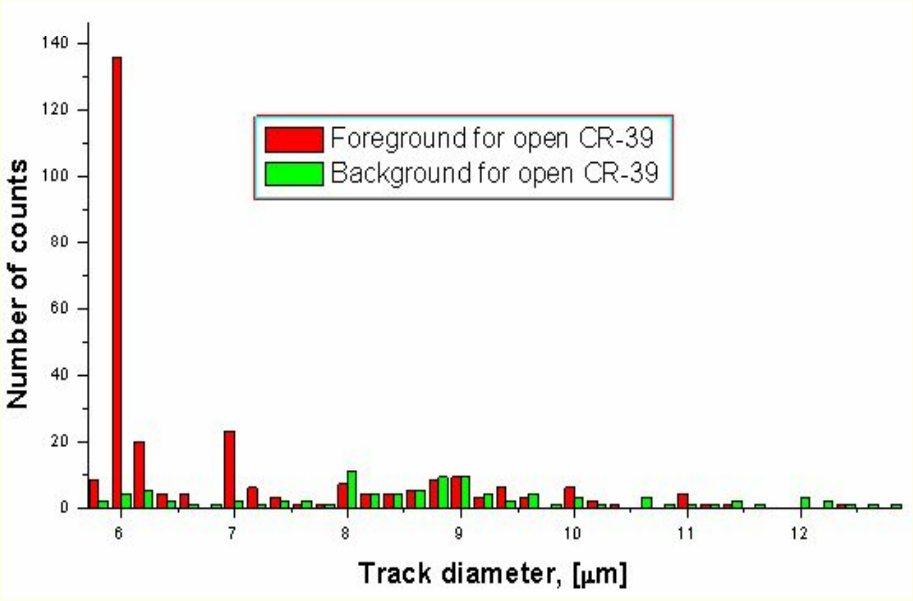
Equation

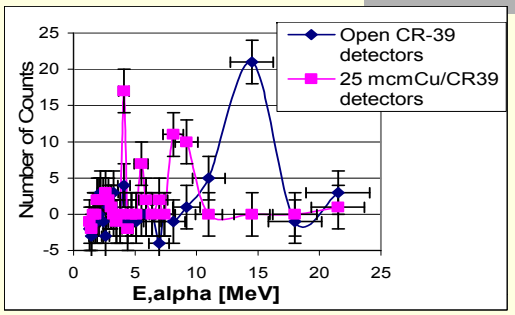
Run Number	*Excess Power (W)*	
	Calculated	Measured
#7	1.9 ±0.6	4.0 ±0.8
#8	0.5 ±0.2	0.5 ±0.4
#18	0.7 ±0.3	0.6 ±0.4

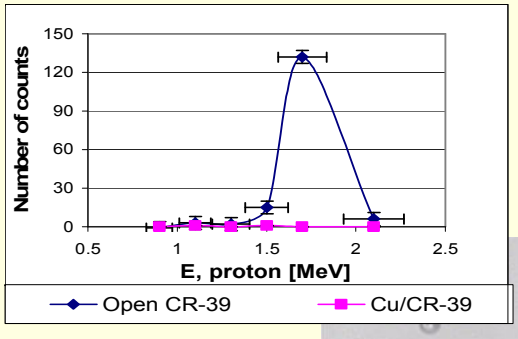
Results from Energy Balance Calculations for Three earlier Thin-Film experiments.

All experiments used Li_2SO_4 in H_2O for the electrolyte and thin-film Ni coated cathodes.

Results #3 -- MeV charged-particles Alpha-Particles and Protons

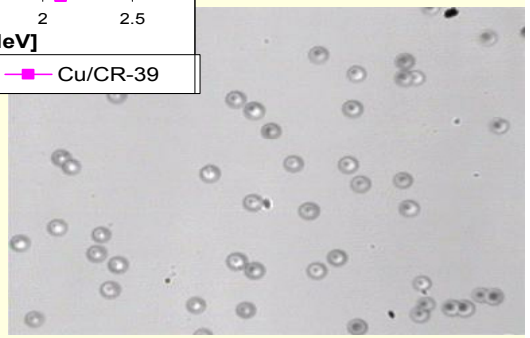






High-energy charged particles: 1.5 - 1.7 MeV protons and 16 MeV alphas.

After background 11- subtracting

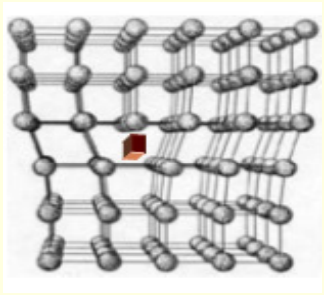


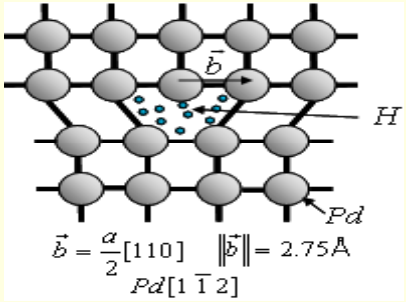
Tracks in CR-39 from 12.0 MeV α-particles; image area S= 0.2x0.2 mm, (X 700)

Our Dislocation-Loop-Cluster Studies

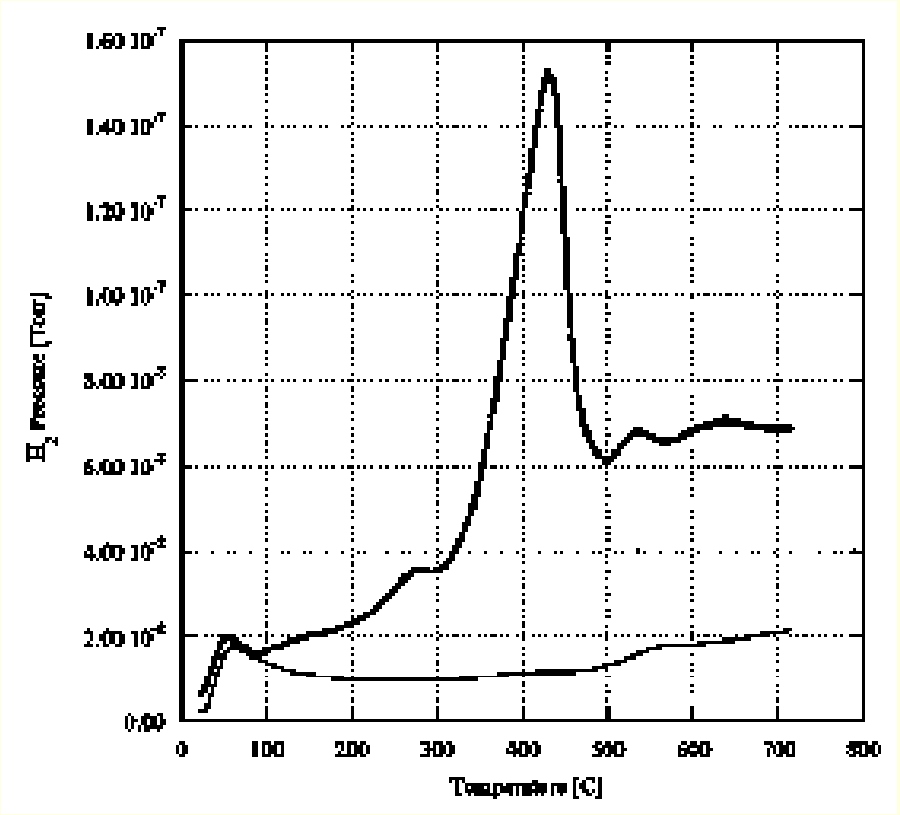
- Pd thin foil – 12 μm
- Loading and unloading deuterium/hydrogen was done by cyclically cathodizing and anodizing Pd foil → dislocation loop and cluster formation

PdO
Pd
PdO





Temperature Programmed Desorption (TPD) Experiment



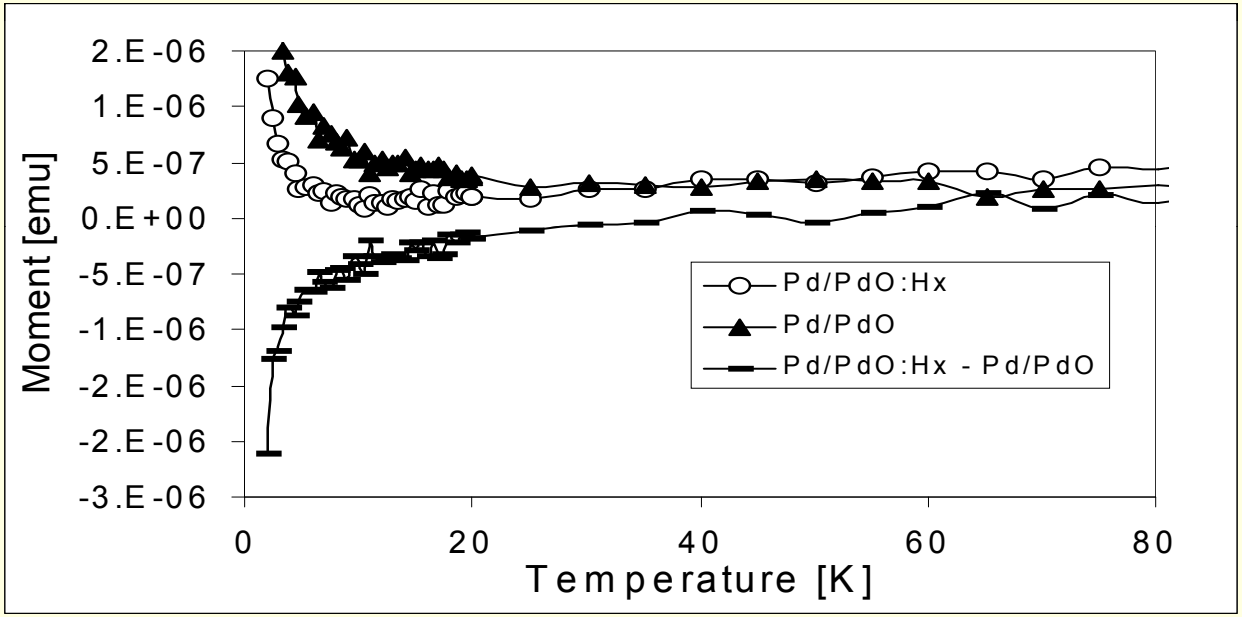
Binding Energy calculation – close to the binding energy between hydrogen and dislocations

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

H/Pd ~ 1.8

After the loading foil was annealed under 300 ^{o}C for 2 hr, the temperature was ramped from 20 ^{o}C to 800 ^{o}C at 9 ^{o}C /min.

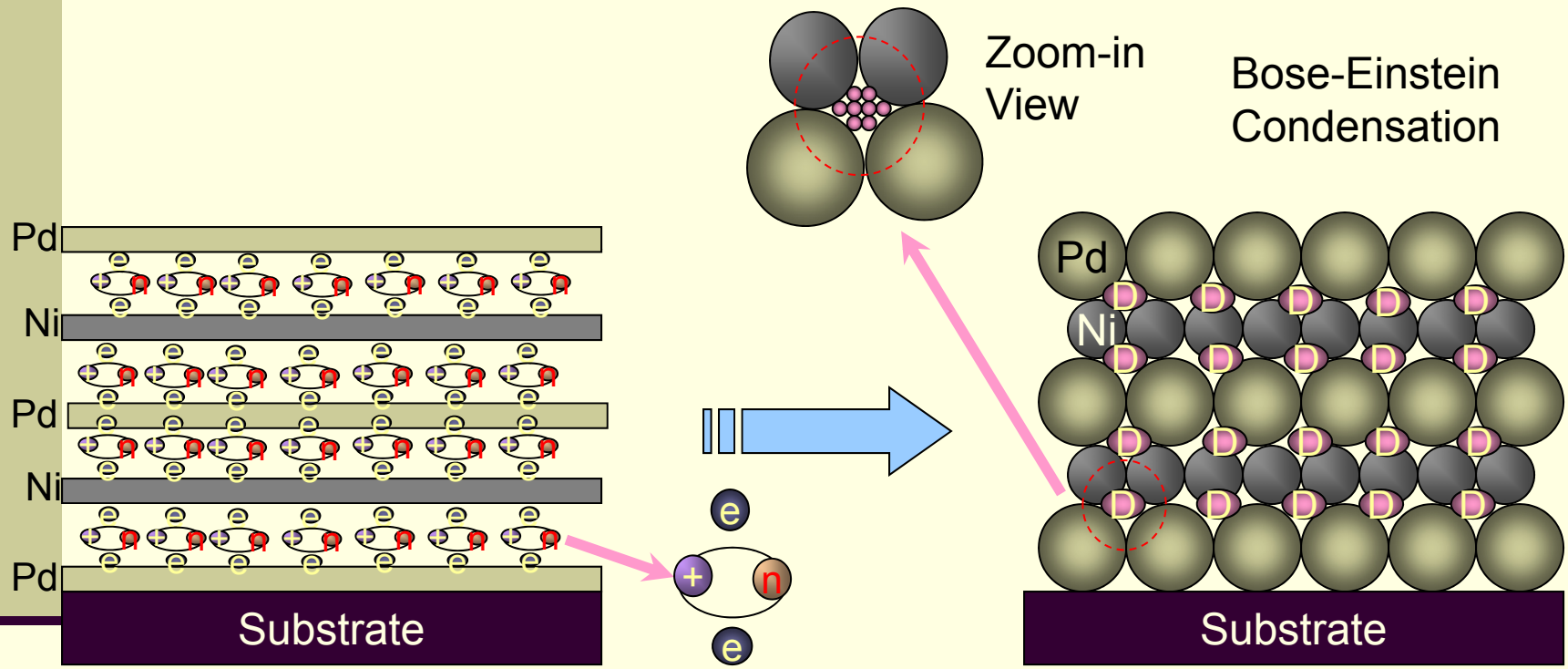
Experimental Magnetic Moment Measurements of Pd:H sample show superconducting state

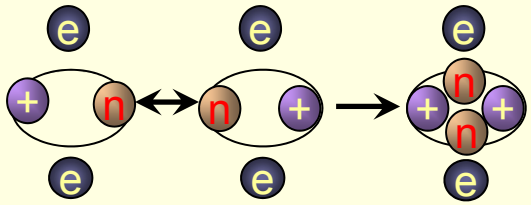


The magnetic moment of H^2- cycled PdHx samples in the temperature range of $2 \leq T < 50$ K is significantly lower than M(T) for the original Pd/PdO.

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

Theory





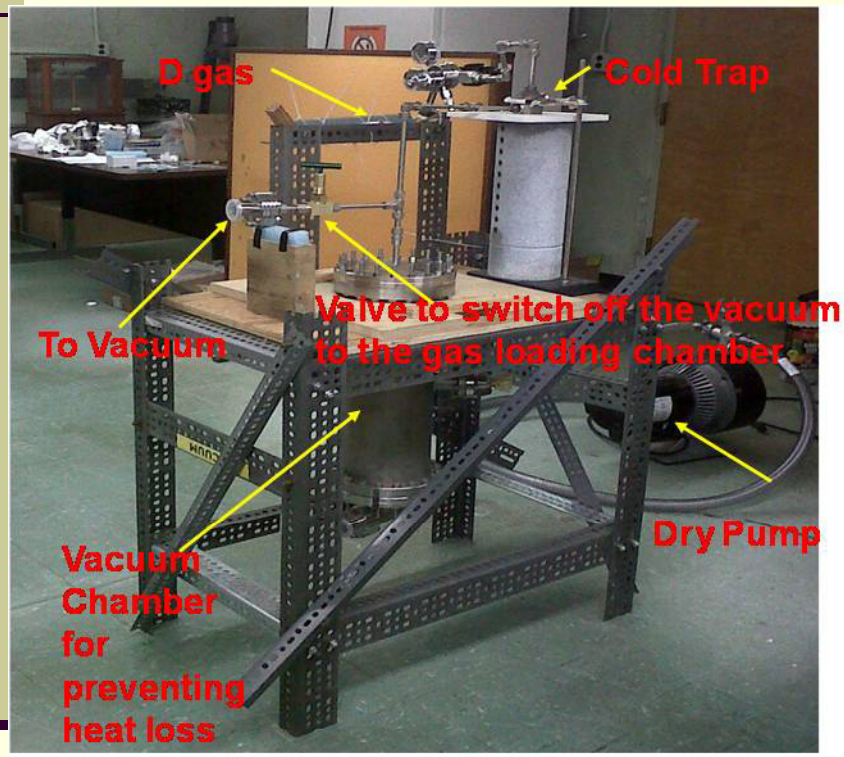
Yeong E. Kim, Theory of Bose–Einstein condensation mechanism for deuteron-induced nuclear reactions in micro/nano-scale metal grains and particles, Naturwissenschaften, 96(7):803-11 (2009)

Conclusion: High density deuterium cluster formation (Bose-Einstein Condensation) at room temperature

How to Trigger The Reaction?

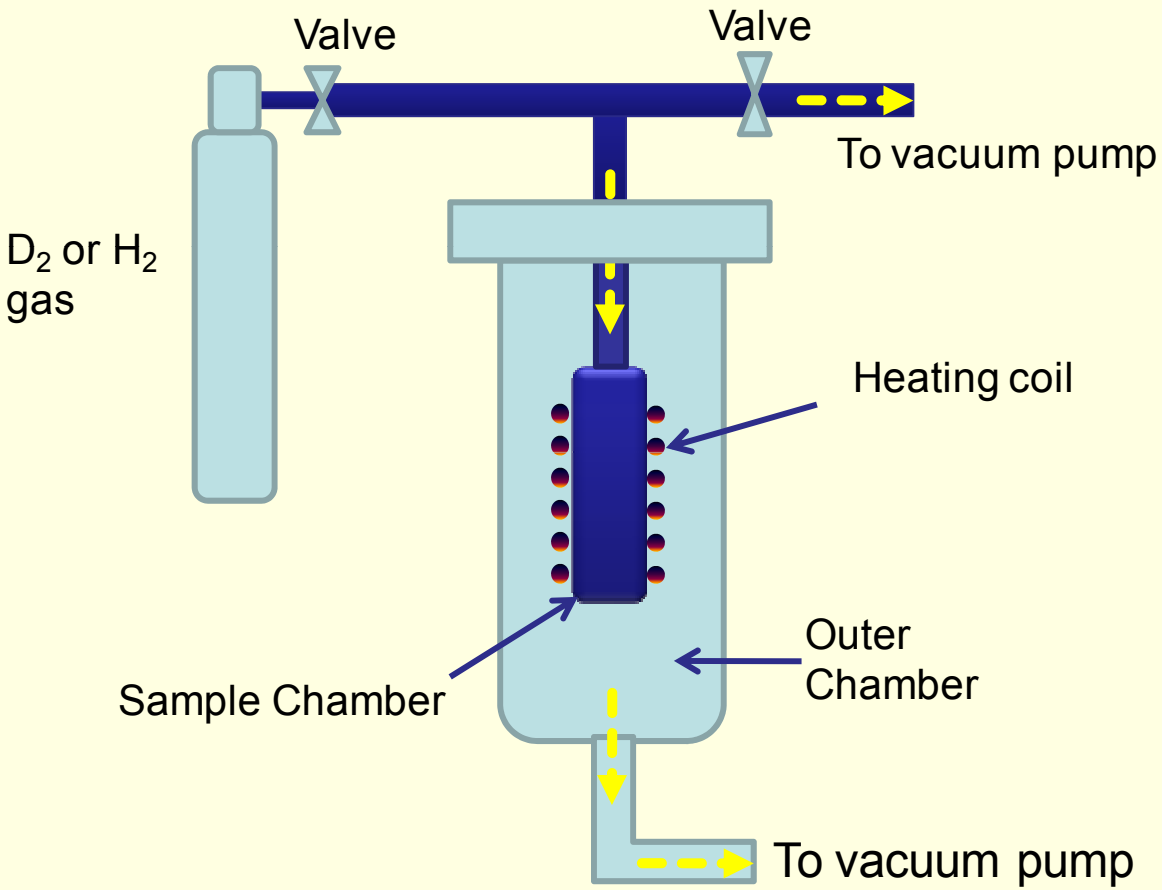
- Electrolysis
- Gas loading
  - Smaller heat capacity
  - Higher temperature change as compared with an electrolysis system.
  - Without the constraint of being limited by the boiling temperature of the fluid
- Glow Discharge
- Low energy laser

Our Gas Loading System



2.2cm inner diameter
25cm^3 total volume

Inside View


Valve
Valve
To vacuum pump
D_2 or H_2 gas
Heating coil
Outer Chamber
Sample Chamber
To vacuum pump

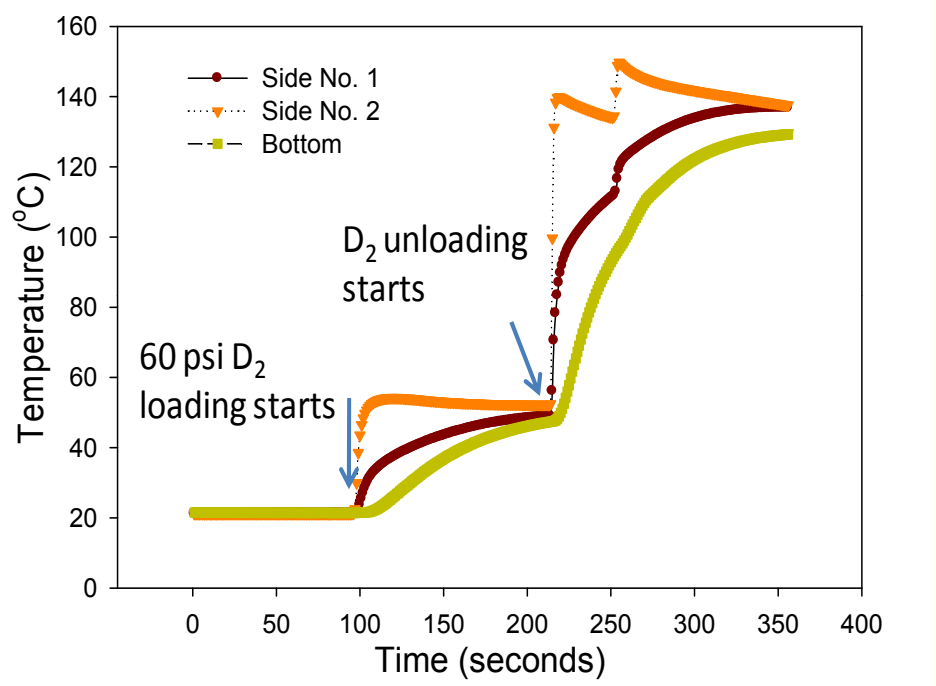
Preliminary Excess Heat Measurement Using Our Gas Loading Calorimetry System

High purity (99.999%) D_2 gas at 60 psi was loaded into 20g ZrO_2Pd_{35} powder under room temperature and then unloaded.

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

Calculation: Energy = $\Delta H \times M_{D2}$

ΔH = -35,100J per mole of D_2 for the formation of PdD_x for x < 0.6;
M_{D2} is the total moles of D2 that combined with Pd



Actual measured energy -- **1479J**

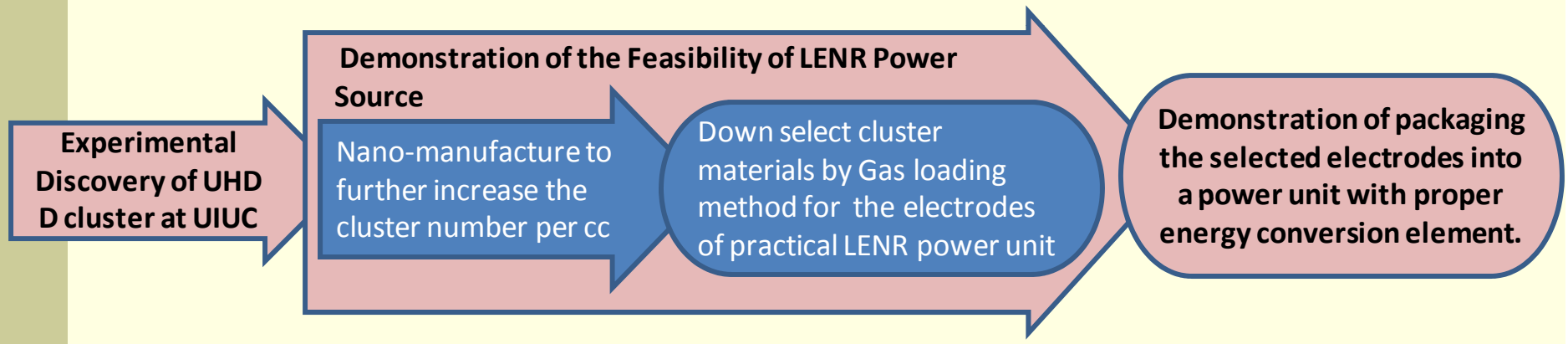
Calculation: Energy =$\Delta T(M_{chamber}\, S_{chamber} + M_{powder} S_{powder})$

Δ T is temperature change, M is mass, and S is the specific heat

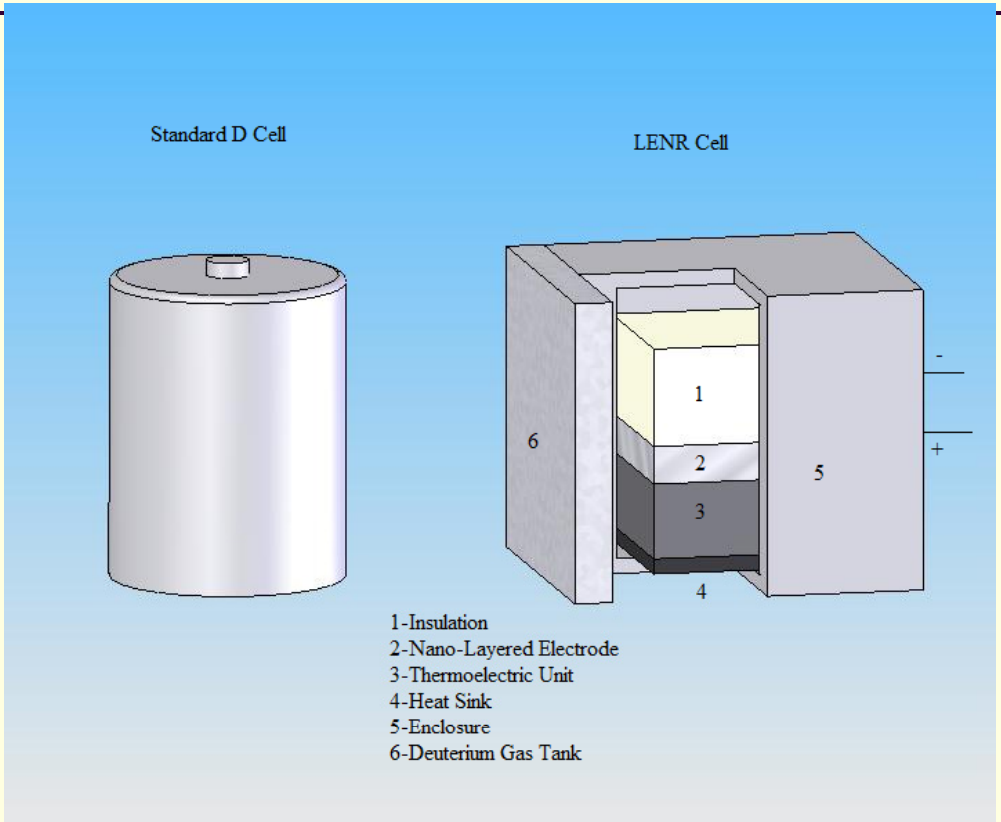
Conclusions

- Experimental evidence confirms cluster formation in dislocation loops.
- Methods to fabricate high loop density under study.
- Experimental evidence of the existence of the excess energy, suggesting the necessity and the importance of pursuing this project further.

Road Map to a Prototype LENR Unit Development



Goal – LENR Small Power Unit



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Conclusion

- Experiments have confirmed LENRs occur by creation of ultra high D-clusters.
- Methods to increase the cluster packing fraction, hence the power density of the electrode have been identified and are under development.
- This provides a “road map” to LENR power cells.
- Such nuclear energy sources would be remarkably “green” and provide a radical new approach to solving our future energy needs.

- Contact: ghmiley@illinois.edu;217-3333772