Distributed Power Source Using LENRs

- George H. Miley
- Erik Ziehm, Tapan Patel, Anais Osouf, Kyu-Jung Kim, Bert Stunkard
- University of Illinois
- Champaign IL, 61821 USA
- ghmiley@illinois.edu

- Work done in support of LENUCO

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

A Vision of the distributed power units

Based on present power density results

Assumes long run times and control achievable

LENR heat unit compares favorably with Radioisotope sources such as Pu^{238}

Basis for power scaling

- Pu^{238}: 540 W/kg
  3 kW = 5.6kg; 0.28L

- LENR: 1kW/kg at 4 atm and room temperature (present data)
  3kW = 3kg; 2.3 L nanoparticles

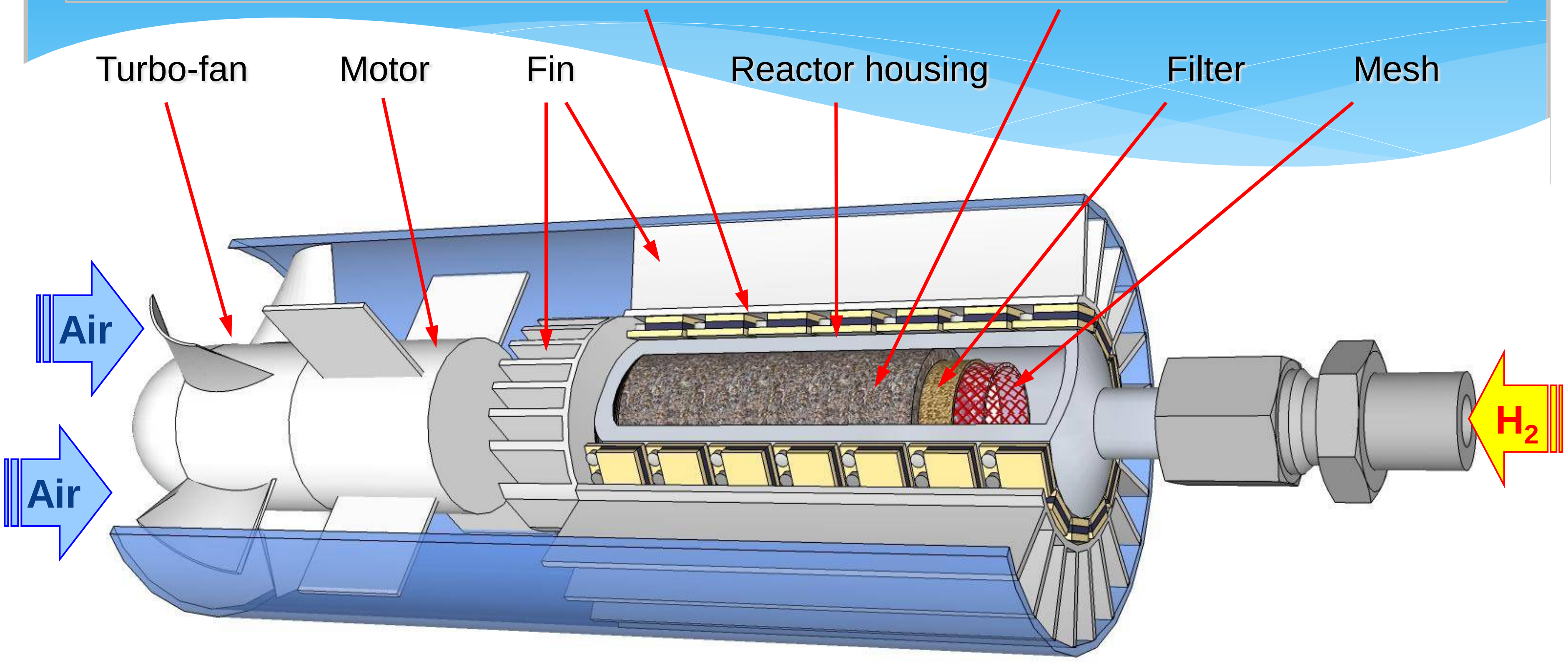
Thus on a weight basis LENR unit offers approximately same power, but uses somewhat larger volume.

LENR-Gen Module

* Conceptual design for modules for distributed power illustrates how simple the configuration is, leading to compactness for ease of location and reduced costs.

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

LENR-Gen Module



A Hydride Gas-Loaded Nanoparticle Electrode Cell
one concept for 1.5 kW units for distributed power. Could be scaled to higher power units with some thermal power handling modification. Alternately for some uses these could be combined in parallel or series for higher powers and for voltage-current matching.

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

LENR for Household Power

* Average household requires 1.5 kWe electrical
  * A 7 kW thermal giving, after conversion to electricity.
  * 1.5 kWe = our standard model for this market.
  * Would use heat for co-generation applications.
  * The cost analysis is based on this unit

Capital Costs

* Capital Costs for first generation 1.5 kWe LENR unit → in the $ 2 / W range
* Estimated total unit cost = $3,000 or $ 2/W installed.
* Comparison: 1/2 to 1/5 of the installed cost for equal size of Solar, Wind or Fuel Cell.
* 2nd Generation of LENR units would lower price even more due to continuing R&D.

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Operational Cost

* Operational Cost is comparatively low after the Initial Investment.
* Replace nano-particles every 6-months, using recycled particles.
  * $500 per reload of nano-particles.
  * Gas and Maintenance costs are low

    → chamber components should not wear out for many years

    thus particle reloading dominates the operational cost

Operational Cost

* Gives operational cost of 7 cents/kWh vs. 15 cents current household average.
* Note: nano-particle reloading costs are equivalent to the cost of natural gas for high-temperature fuel cells, or the cost of energy storage/electrical purchase for solar when the sun is down.

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

LENRs payback times

* First generation LENRs payback times are very short → 3 years.
* COE of 7 cents/kWh for first generation LENRs

→ 3 year payback period, after which a cost savings/unit →

$ 1000/yr is enjoyed.

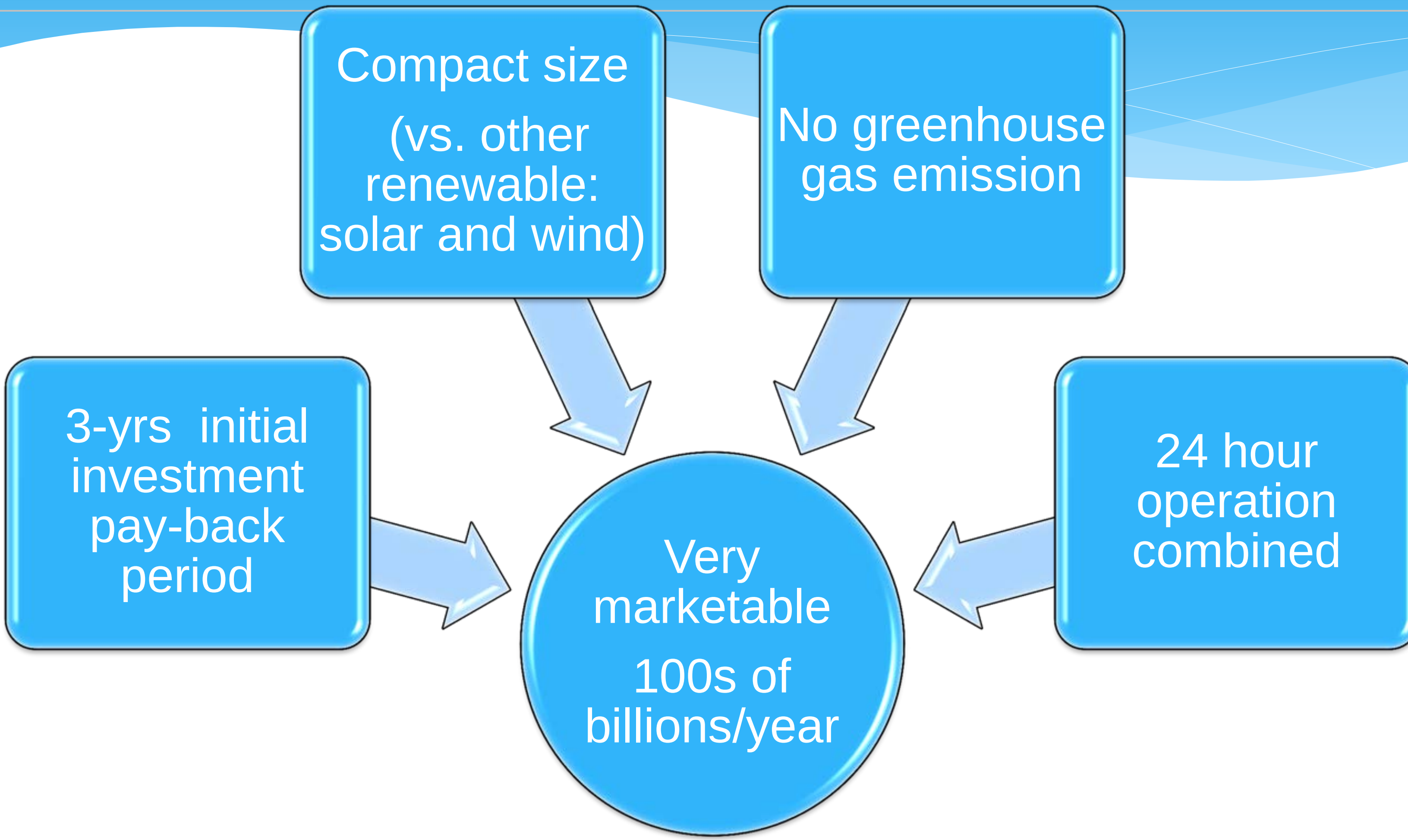
ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

LENRs payback times

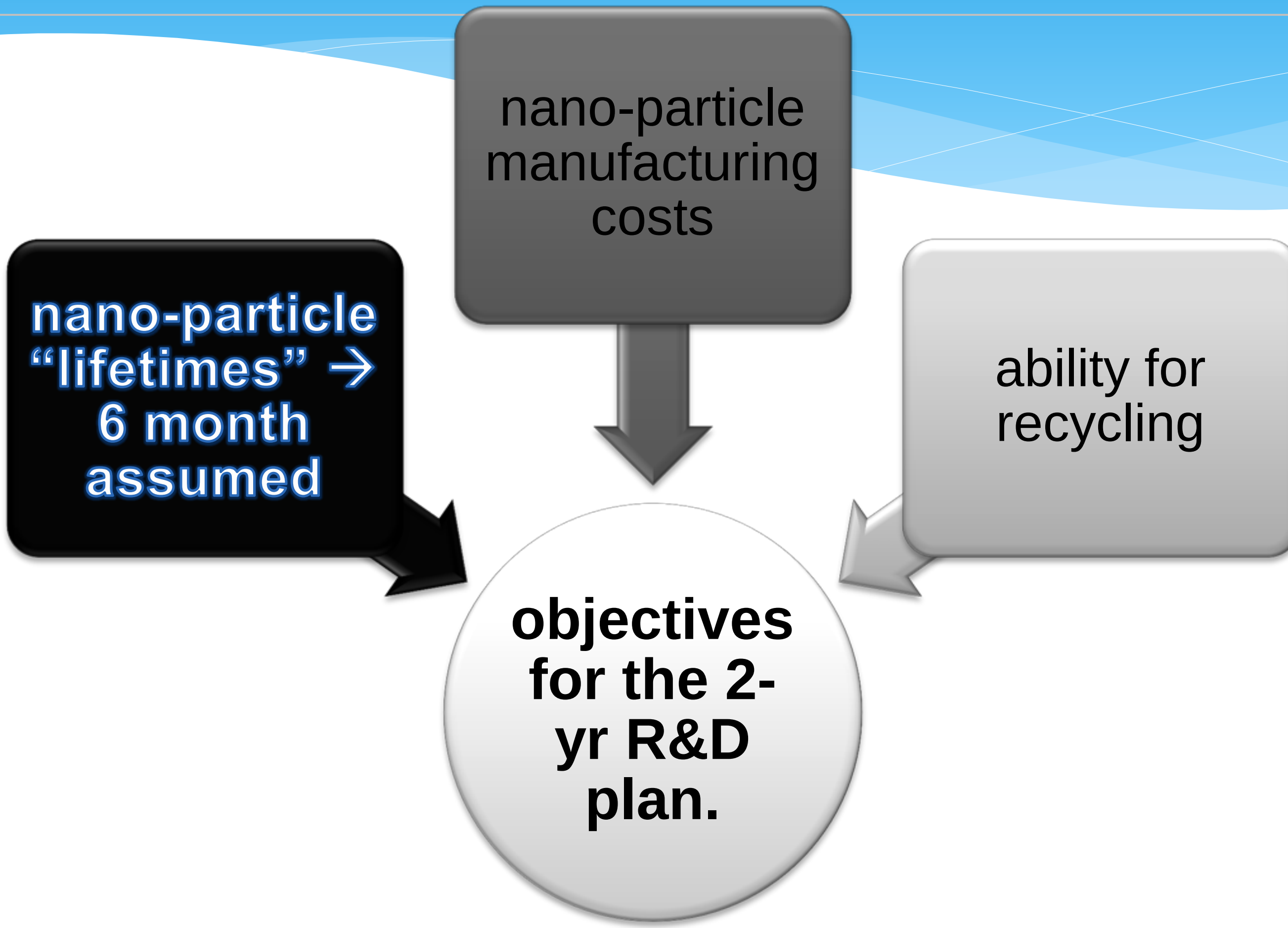
- Compare: solar panels are quoted to have about a 10 year payback, and fuel cells even longer.
- Future price reduction of 5~20% / yr are projected due to nano-particle improvements.
- Historically, other renewable power has received government and state incentives to off-set costs.
- But incentives may not be necessary for LENR .

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Market potential



Major uncertainties



Operation based on clusters

Our recent LENR work and ultra dense H/D cluster

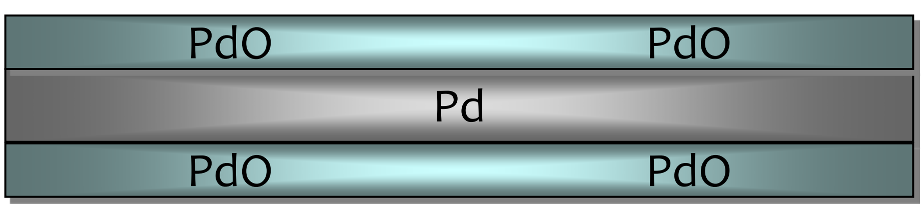
- Previous experiments using thin-film beads and plate type electrodes formation.
- Evidence for Clusters and Nuclear Reactions.
- Gas loaded nano-particle experiments.
- LENR Power Source Applications.

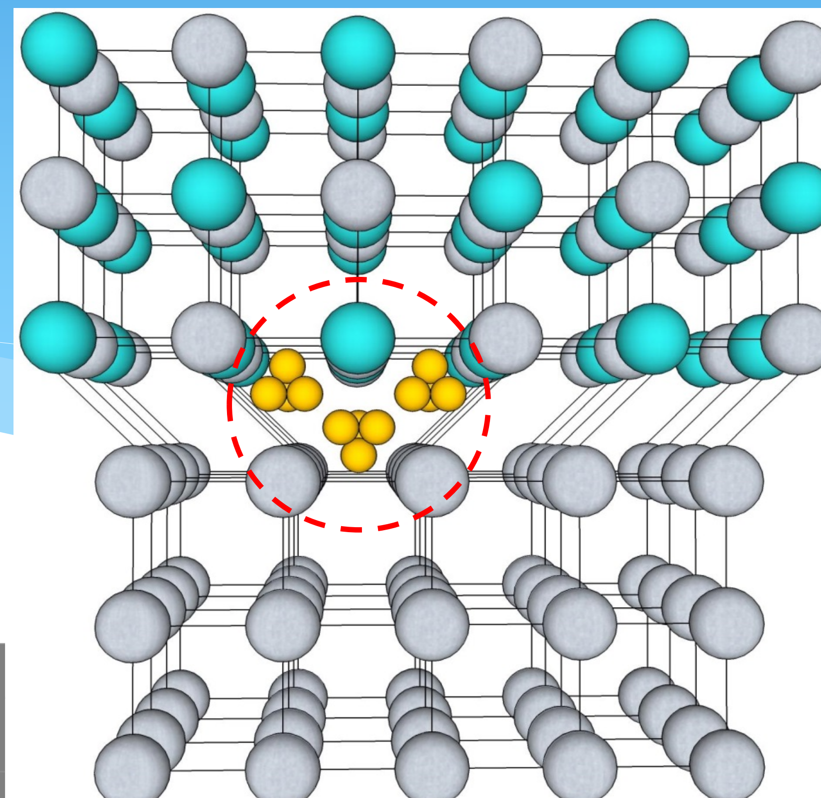
Earlier Experiments with thin films leading to use of clusters for reproducible reactions

Dislocation-Loop-Cluster Studies with Thin Films. Clusters of D or H Form the Nuclear Reactive Site for LENR.

- Pd thin film = 12 µm
- Loading and unloading of D/H done by cyclically cathodizing and anodizing of Pd film

→ dislocation loop and cluster formation

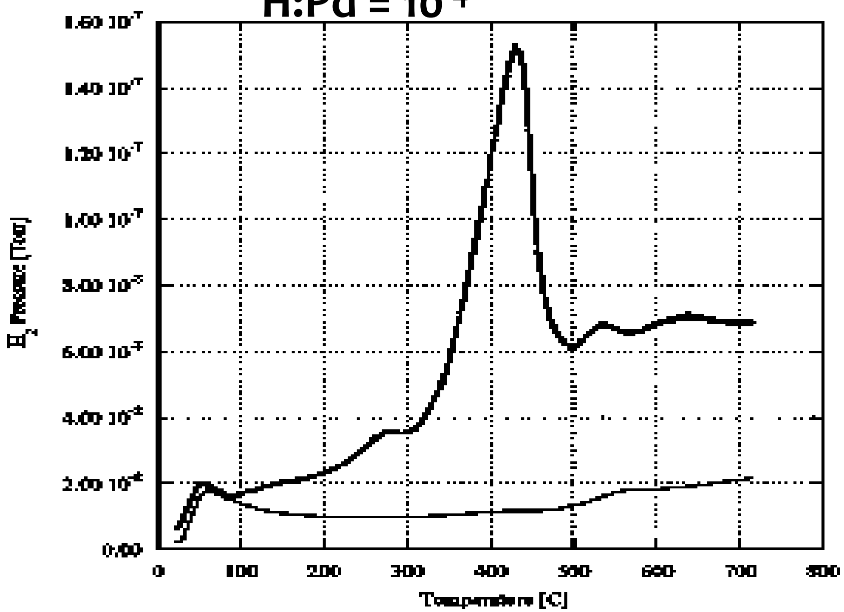




ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Understanding Clusters and Demonstrating their almost Metallic Density Hydrogen Characteristic Temperature Programmed Desorption (TPD) and SQUID Measurements

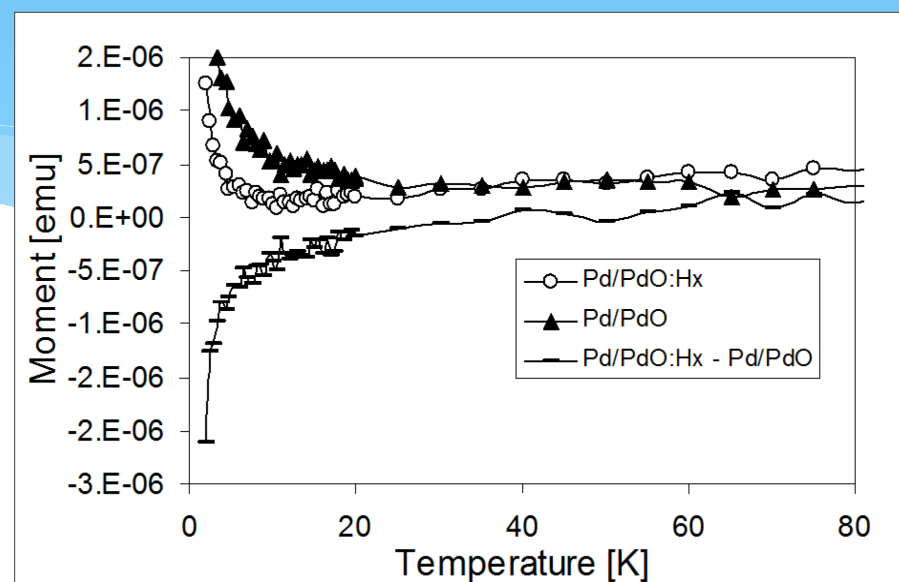
H:Pd = 10^{-4}



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

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

The magnetic moment of H_2- cycled PdHx samples in the temperature range of $2 \leq T < 70$ K is significantly lower than M(T) for the original Pd/PdO.



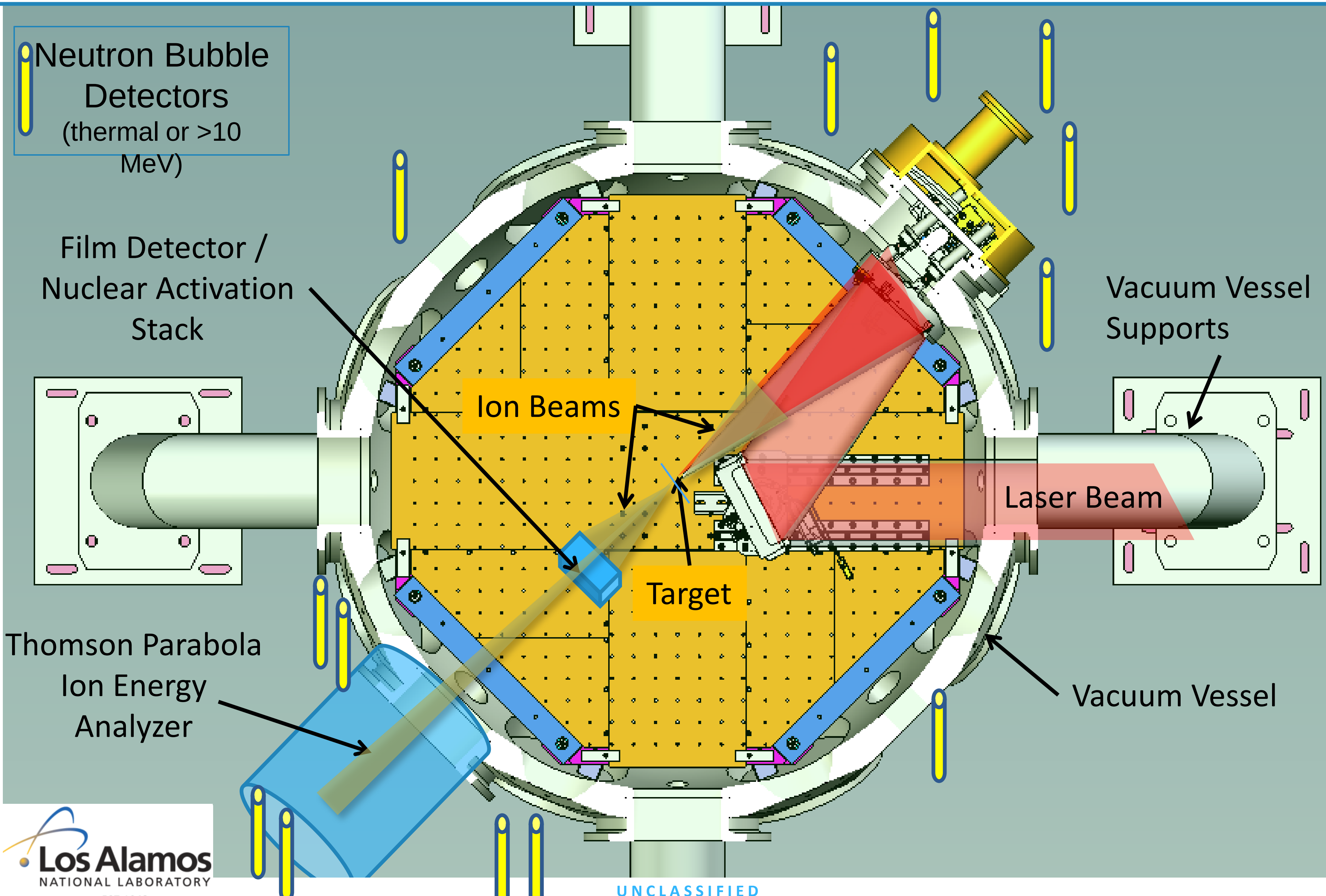
ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Alternate Studies with Laser Acceleration - Initial Experiments at LANL

- The thin film cluster results are quite encouraging for laser acceleration of high energy D beam, warranting experimental validation
- First step – initial experiment at TRIDENT
  - Goals
    - Verify extraction from cluster in tradition TNSA mode
    - Verify earlier estimate of accelerated deuteron beam energies

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Deuteron Acceleration Experiment In LANL



TRIDENT laser parameters for experiment

- Peak Intensity was 2 * 10^20 W/cm^2
- Laser was focused with an f/3 Off-Axis-Parabolic M irror
  - And focused to a near diffraction limited s pot
- Pulse length 600 +/- 100 fs
- Energy 80 =/-10 J
- Center wavelength 1.054 microns
- Pre-pulse contrast >10^10 (in intensity)

More Parameters

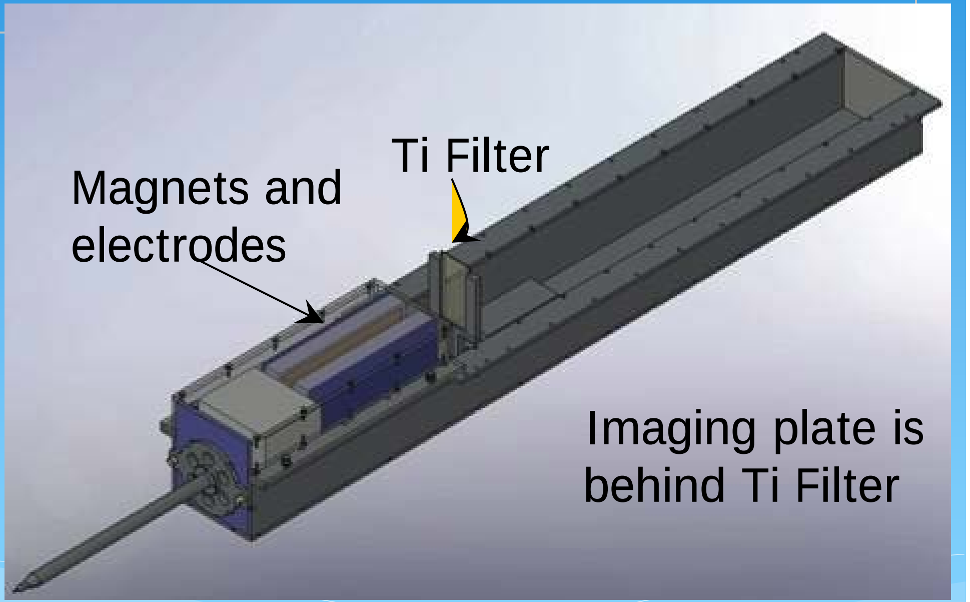
* Diameter of the Vacuum Chamber: 1.5m.
* Diameter of the laser beam: 7 um
* RCF stack 5x5cm^2
* Pinhole diameter on RCF: 3mm

* D cluster target
  * 2X2mm, 12micrmeter thick, supported on glass fiber.

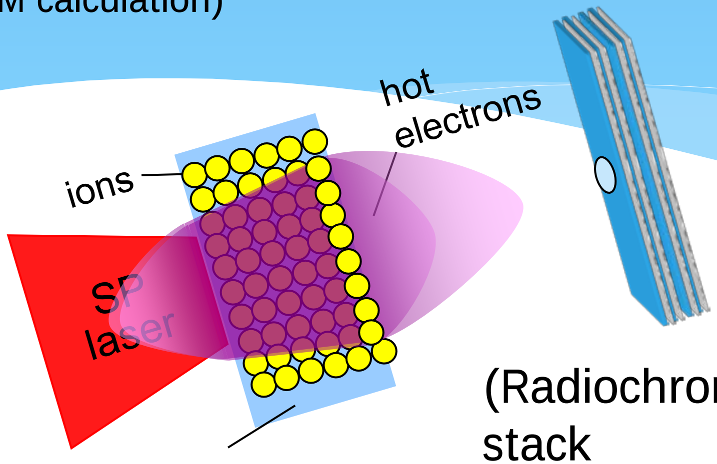
More details

Imaging plate: made by FUJIFILM Global™. It uses a phosphor layer ($BaFBr_{0.85}I_{0.15}:Eu$) that when exposed to radiation stores energy as defect centers in the crystal lattice

In some cases, a 100 micron Ti foil was placed in front of image plate to filter out C ions below 100 MeV and deuterons below 5 MeV. (according to SRIM calculation)



Thomson parabola



(Radiochromic Film) RCF stack

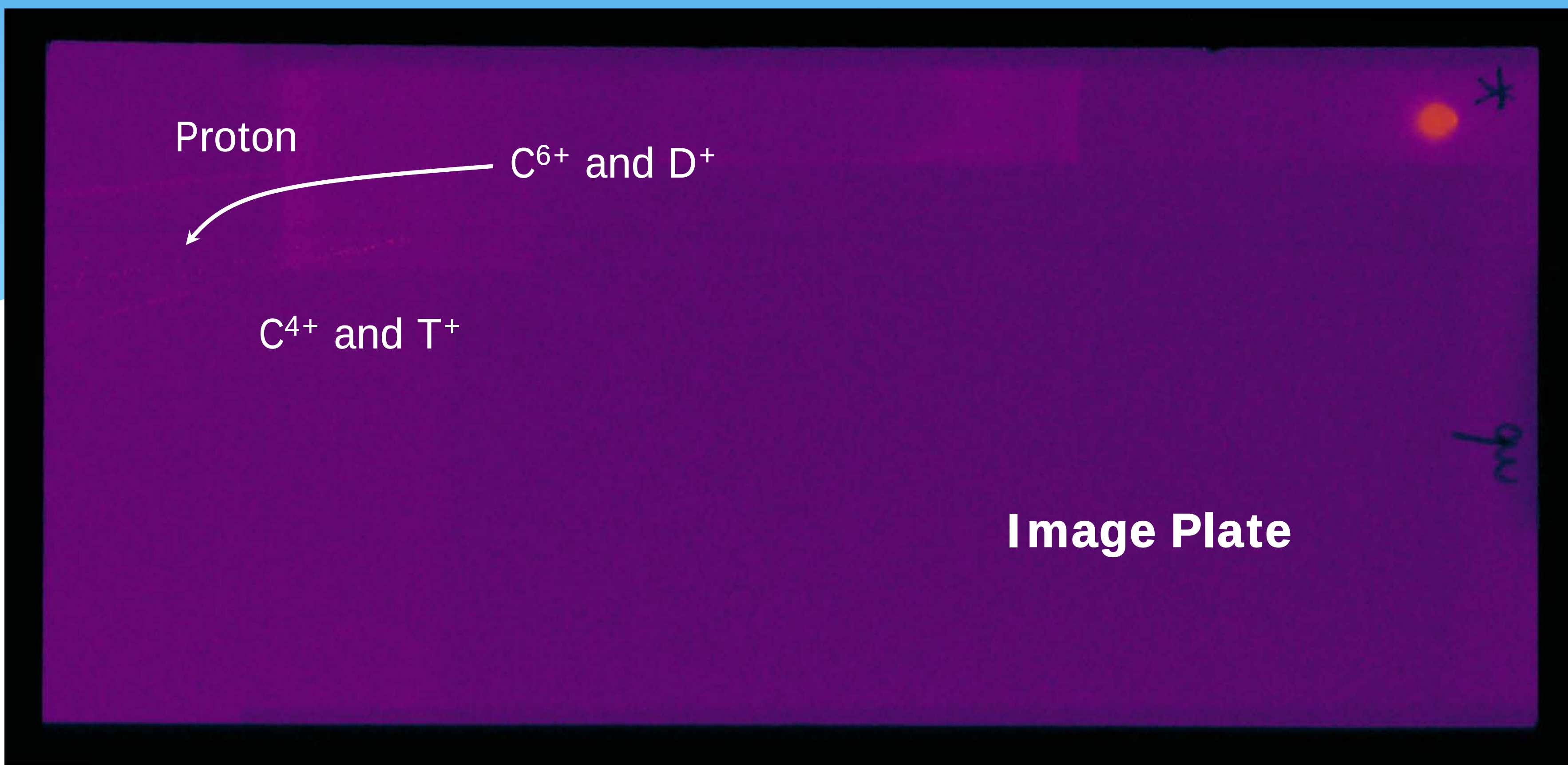
Three targets shot to date --some results shown next

* Three shots performed in first study to gain insight into this ne type of convertor foil and deuteron acceleration from clusters.
* Some representative data are shown next
* After improvements, a next campaign will involve more target shots to study scaling issues and to obtain better quantitative data

Ion Trace of PdD Separated by Thompson Parabola WITHOUT Ti Filter

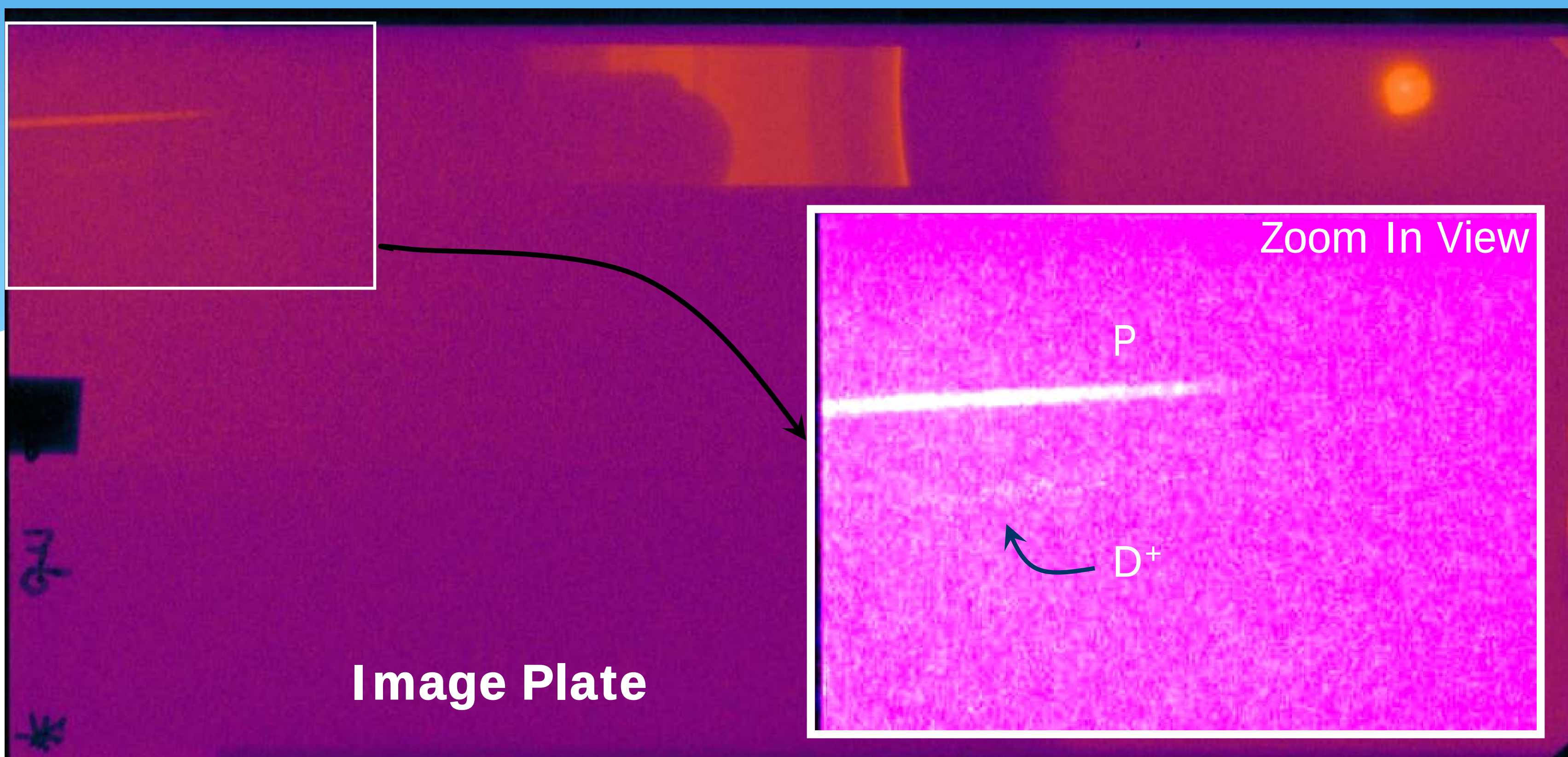
Laser Energy in 91.2J out 75.1J , Duration 559 fs

Bandwidth 2.31nm



Ion Trace of PdD Separated by Thomps on Parabola WITH Ti Filter

Laser Energy in 81.9 J out 67.1



Comments –Exp results

* Demonstrates acceleration from clusters
* Flux and energy depressed by impurity protons (and C?)
* Conclusions - next experimental campaign
  * Continue to improve cluster packing fraction
  * Reduce contamination (p and C).
  * Obtain more insight from ongoing supporting simulation studies.

Conclusion

Added evidence (and use of) cluster formation and systematics

* Future experiment should focus on removing surface contamination layer to avoid interference with deuteron acceleration.
* In-chamber glow discharge cleaning will be used

Recent work is designed to extend the thin-film technique to gas loaded nanoparticles for LENR

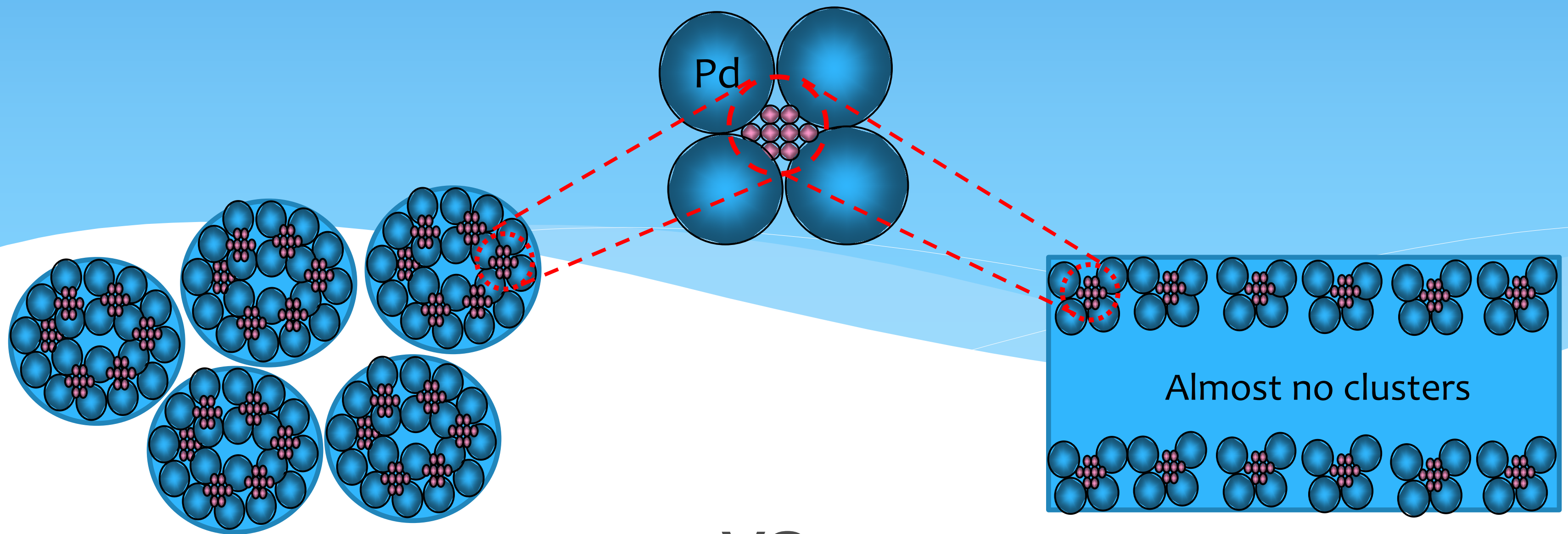
- Larger surface area particles
  - → Lower input power needed
  - → Larger “Excess Power”.

- **Avoids constraint of being limited by the boiling temperature of the fluid.**

Cluster Formation in Nano-Materials

Clusters mainly form in pores close to the surface.

Nano-Materials have more surface area, thus have good ability to form abundant clusters.

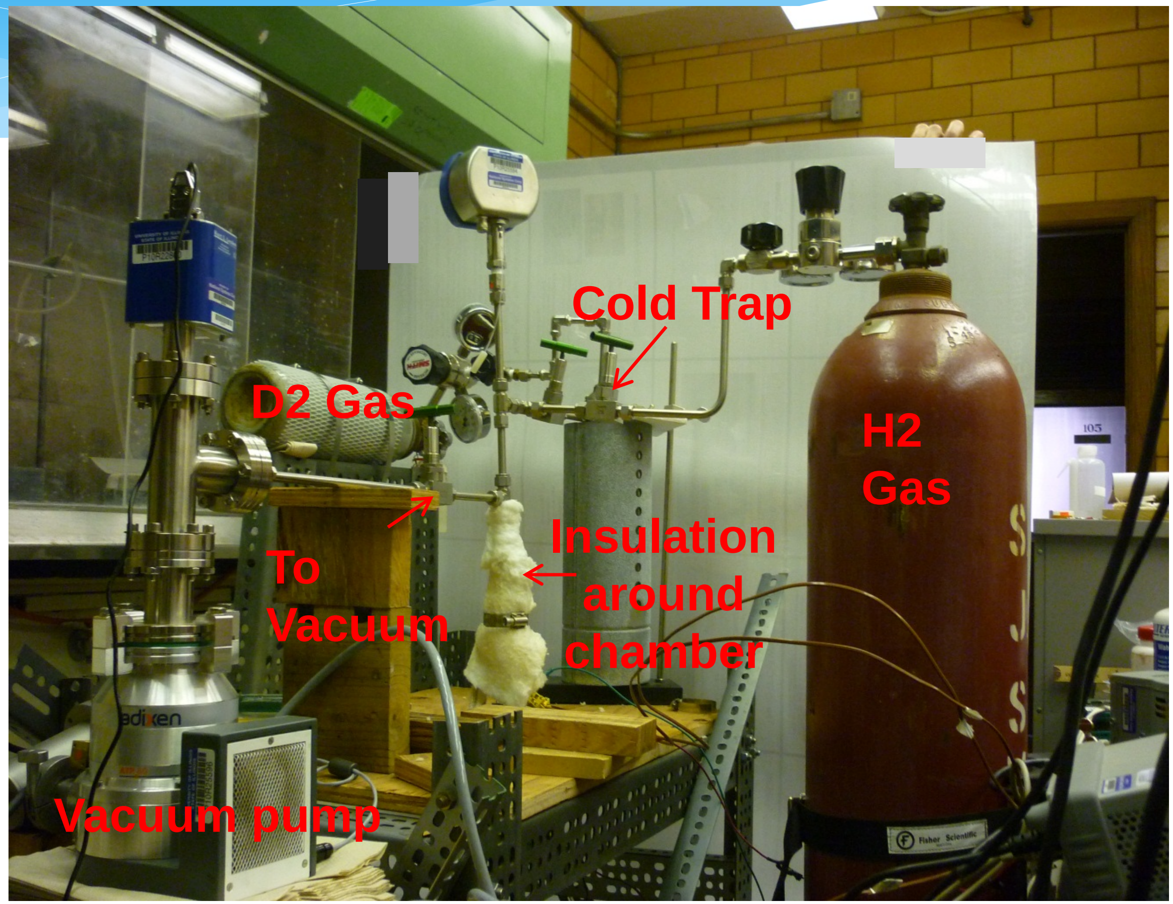


Nano-particles

VS.

Thin film

Gas Loading System for Nanoparticle

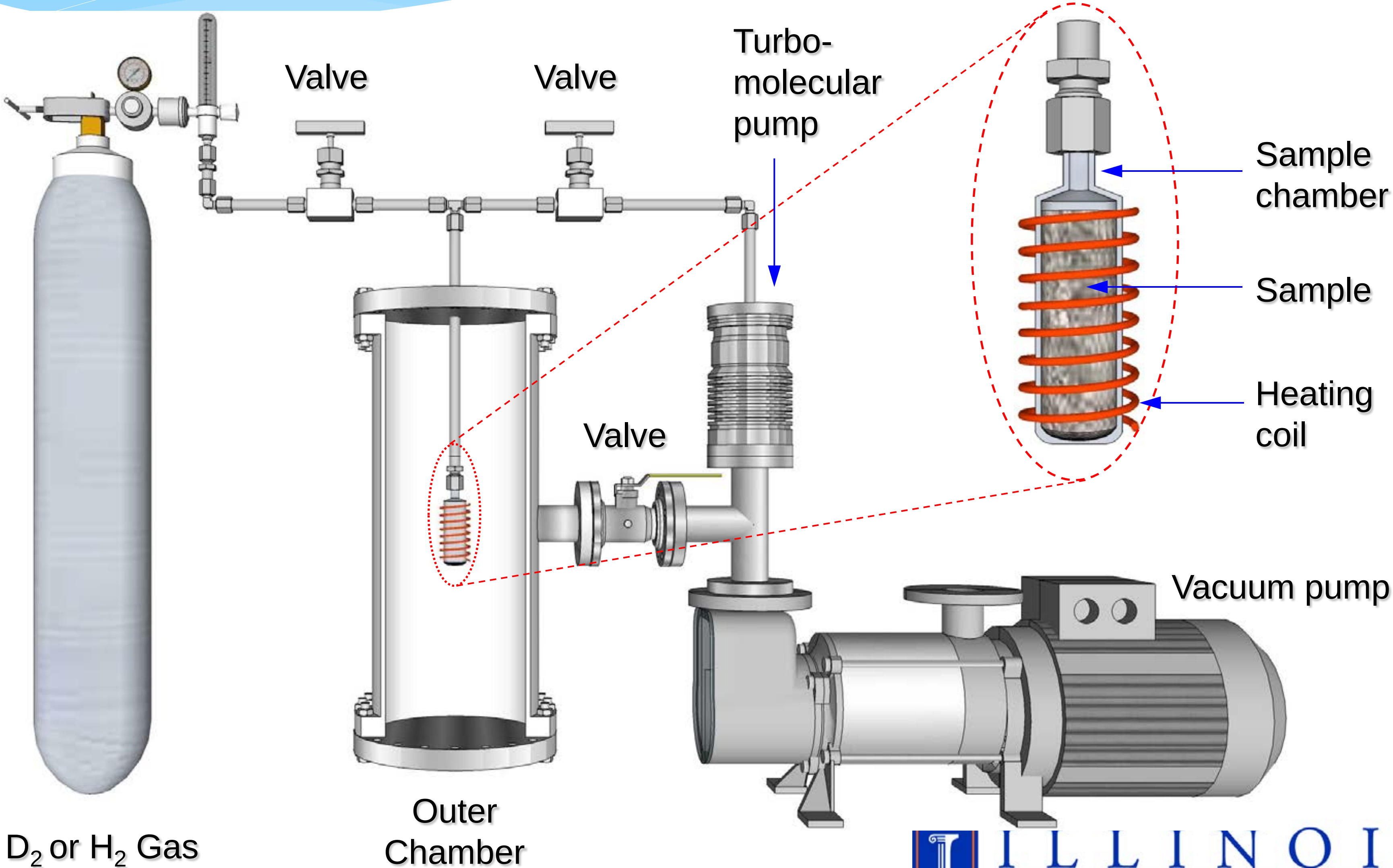


2.2cm inner diameter
$25cm^3$ total volume

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Schematic view

* In some experiments, outer chamber is replaced with insulation for ease of assembly



Comments about Nano-Particles

- 3 different types of alloys; 4~5 components are used
- The alloys are milled and annealed to form nano-particles.
- Details are covered in one of our patents recently issued.
- One Pd rich alloy; A is for D_2 loading.
- Two Ni rich alloys; B, C are for H_2 loading.

Particle composition

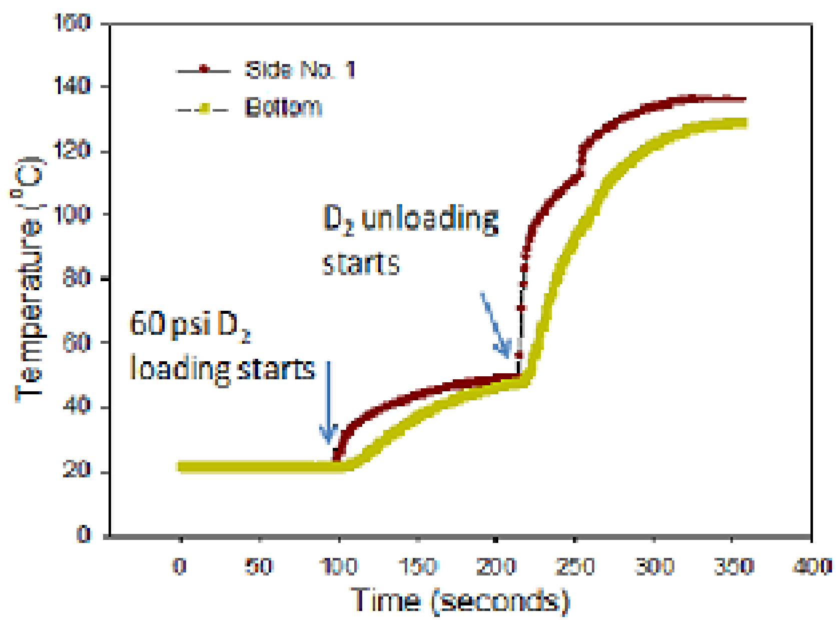
Particle Type	Particle Composition
Type A	Pd-Zr
Type B	Pd-Zr-Ni (High Ni, Pd)
Type C	Pd-Zr-Ni (High Ni, Low Pd)

Two types of experiments: Kinetic and Adiabatic

Kinetic Measurement Using Our Gas Loading System to Illustrate Key Features.

Note; dominate "input power" due to chemical reaction contributions when loading, deloading.

- High purity (99.999%) D_2 gas at 4 atm, Room Temp, 23g nanoparticles Type A
- Absorption: Exothermic chemical reaction
- Desorption: Endothermic chemical reaction
- Chemical reaction Energy = $\Delta H \times MD_2$
- ΔH = 35,100J per mole of D_2



Energy analysis of this 300 second Kinetic Measurement Shows "Excess Energy" production attributed to LENR.

Absorption

Exothermic energy from chemical reaction --- 690J

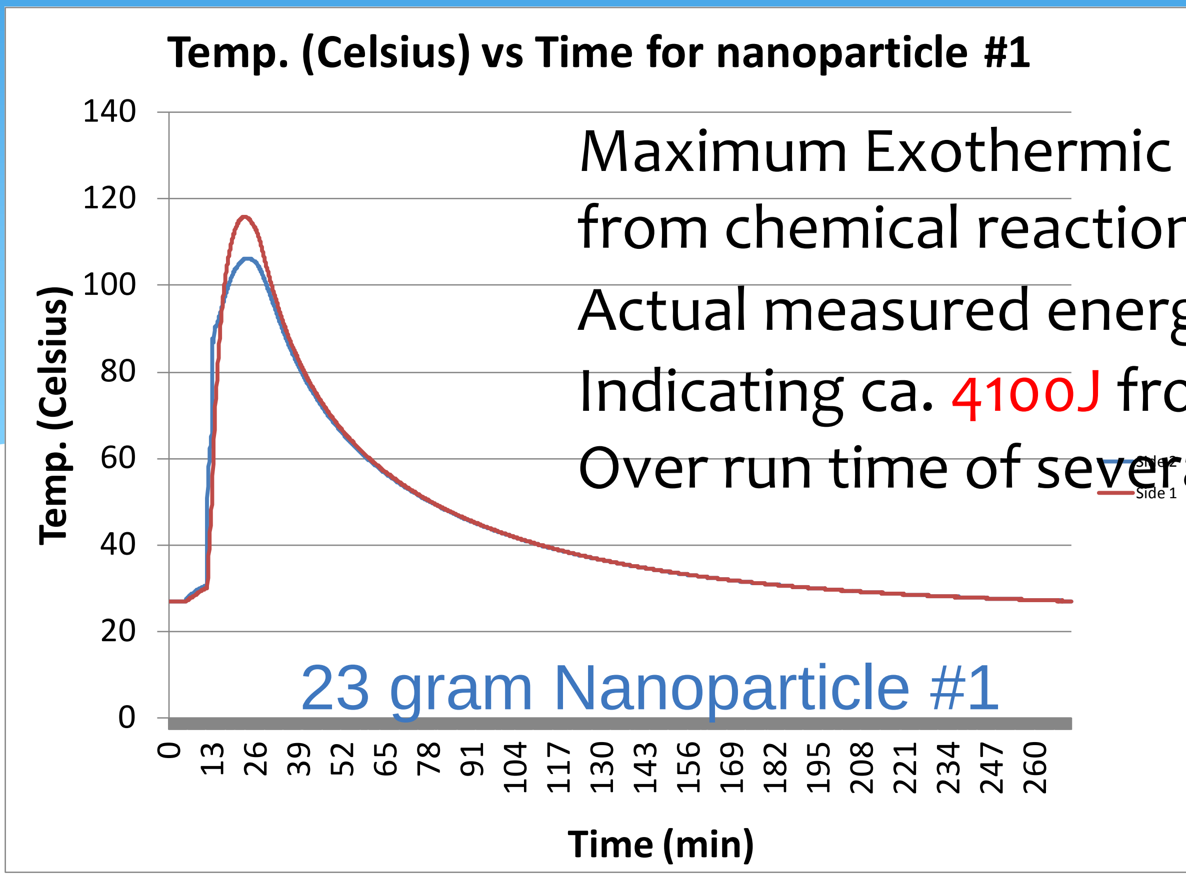
Actual measured energy : 1479J – roughly double the possible chemical contribution. Added energy is attributed to LENR reactions.

LENR (Nuclear) Power Density : ca. 1kW/kg at 4 atm., over short run 300 sec. time

Desorption

Endothermic chemical Reaction – should show rapid temperature drop, but instead an increase is observed – attributed to continuing LENRs produced by increased ion flow out of particle during desorption = "life after death"

Extended kinetic experiment
The Chemical contribution only occurs once : during initial pressurization. Thus longer Run demonstrates larger LENR energy vs. chemical: Here about 7X.



Maximum Exothermic energy from chemical reactions --- 690J

Actual measured energy -- 4769J

Indicating ca. 4100J from LENR

Over run time of several hours

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Our approach to temperature control for long ~ constant temperature runs – requires control method – e.g. pressure variations to MAINTAIN ION FLOW IN PARTICLES as shown in earlier kinetic energy measurement. At the same time the control band will be set at the highest possible temperature to achieve efficient energy conversion to electricity. This maximum temperate will be limited by the need to avoid damage to the nano-particle.

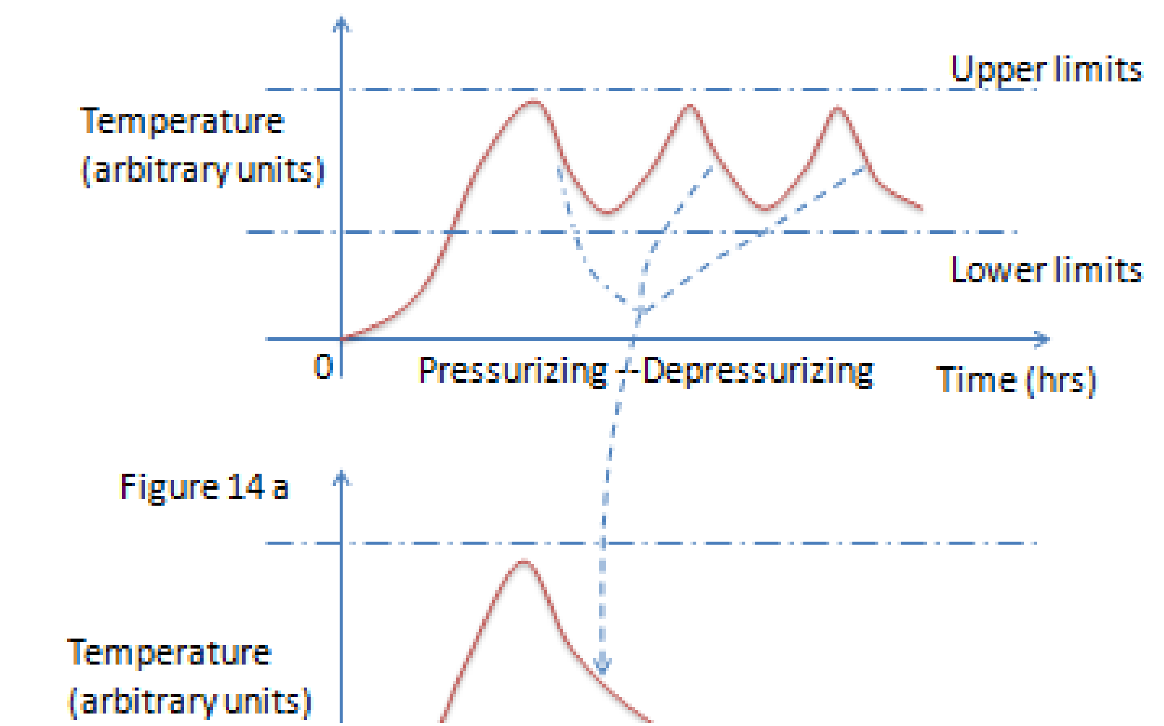


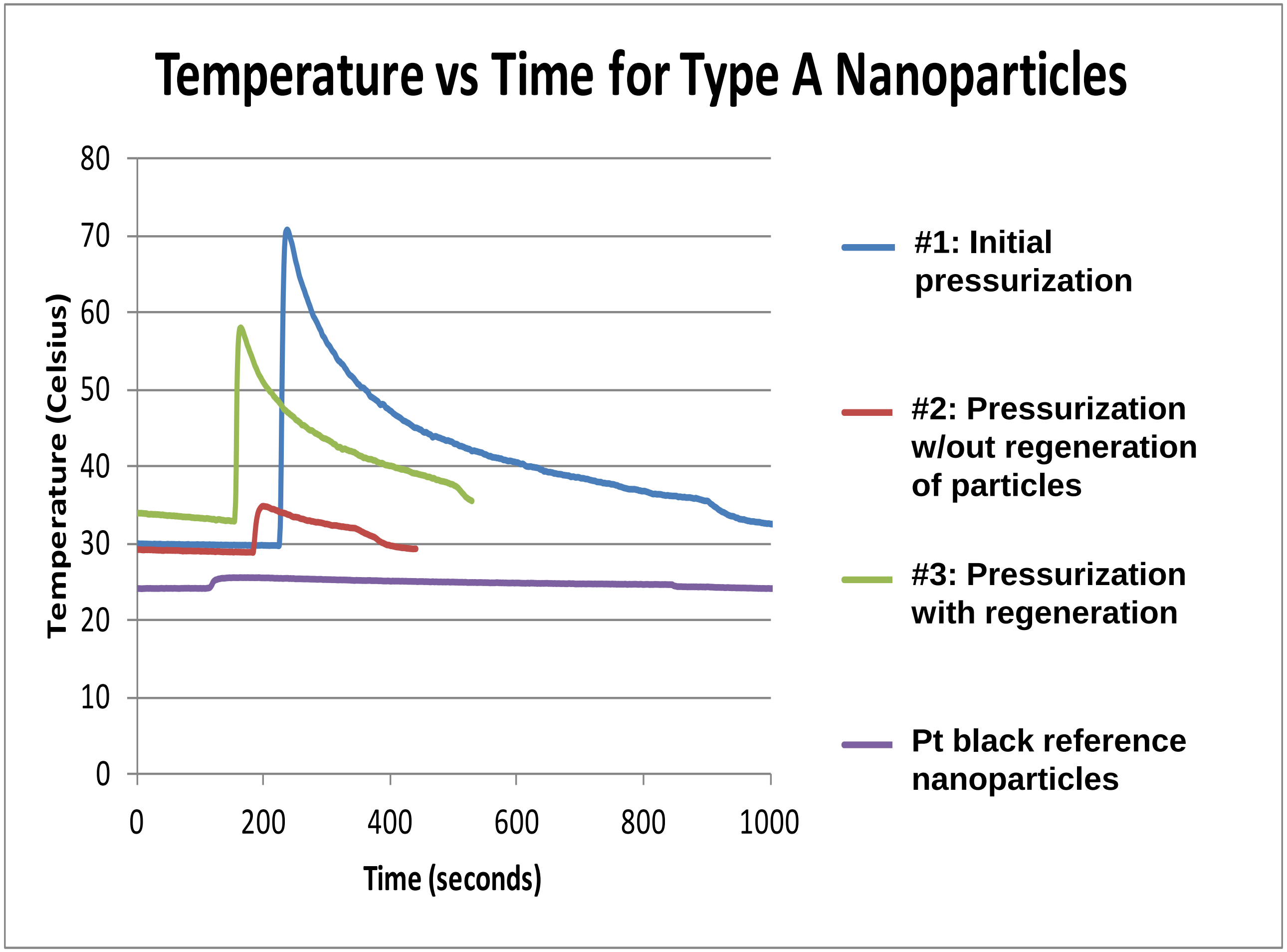
Figure 14 a

Very short run time experiments with small particle weight loading provide adiabatic conditions for comparison of nanoparticle performance

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Adiabatic Experiments: Positive regeneration effects. Pt Black baseline reference data

* Outer chamber used



ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

ADIABATIC EXPERIMENTS FOR COMPARISON OF NANOPARTICLES.

Measured Output Energy for the Initial Temperature Increase Compared to Exothermic Energy from Chemical Reactions

Run #	Nano Particle Type	Mass (grams)	Delta T (Celsius)	Total Energy (Peak)	Total Energy density (J/g)	Initial Temp. to Peak Temp. (sec)	Peak Power Density (W/g)	Chemical Energy (J)	Measured Peak Energy minus Chemical Energy (J)	Gain
1	Type **A**	2.2	31.55	972.05	441.84	14.00	31.56	74.85	897.21	12.0
2	Type **A** (same particles from run 1)	1.9	4.95	151.96	79.98	16.00	5.00	64.64	87.32	1.3
3	Type **A**	1.8	25.05	768.01	426.67	10.00	42.67	61.24	706.77	11.5
4	Type **B**	11.1	90.90	3588.88	323.32	95.00	3.40	271.29	3317.59	12.2
5	Type **C**	6.4	84.90	2754.00	430.31	98.00	4.39	170.76	2583.24	15.1
6	Type **C** (same particles from run 5)	6.4	6.80	220.58	34.47	76.00	0.45	170.76	49.82	0.3
7	Type **C**	3.2	27.10	846.04	264.39	78.00	3.39	85.38	760.66	9.3

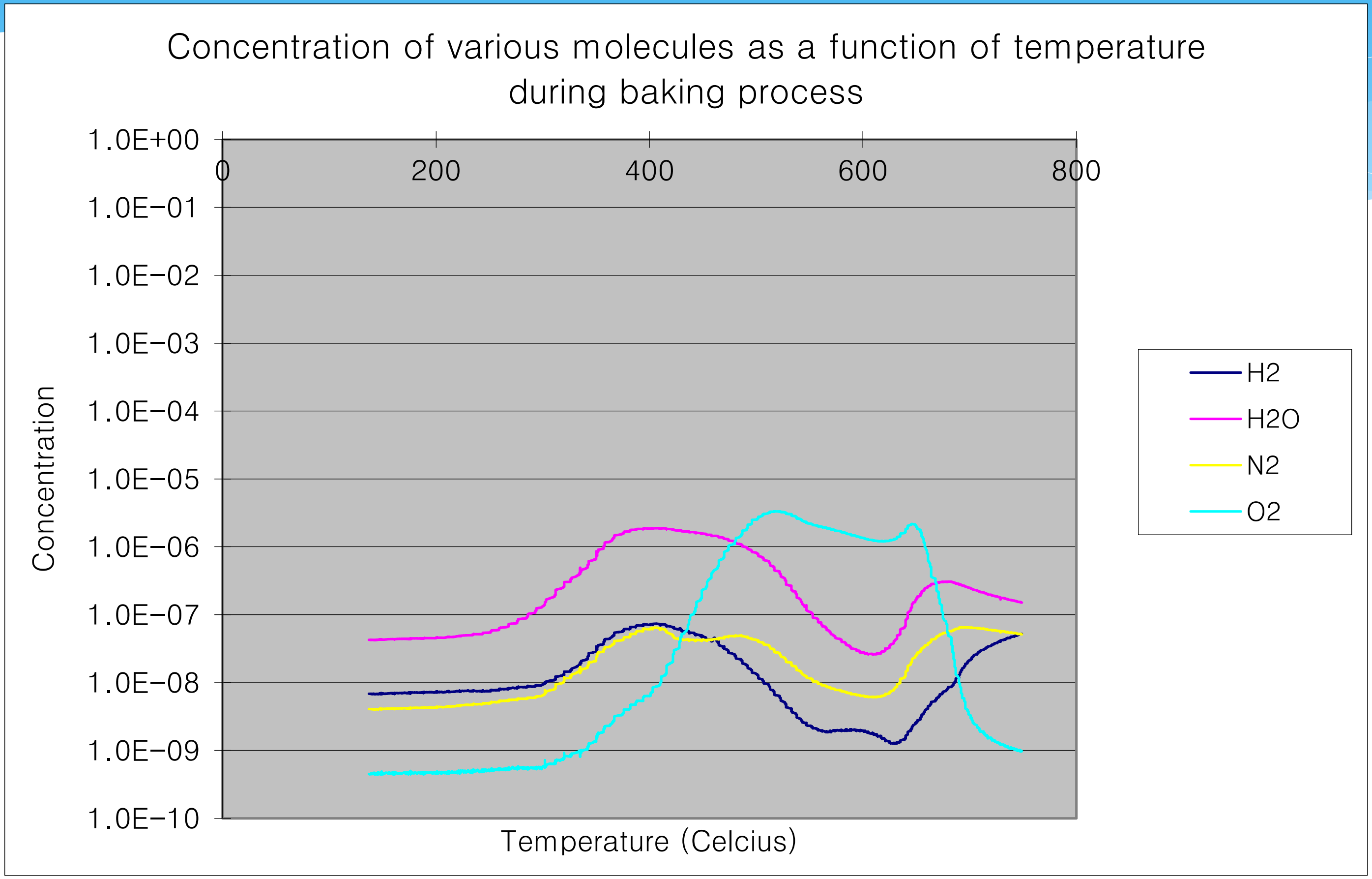
Peak Power as a function of temperature: Particles A & B

			Particle A	Particle B
#	Average starting temp (C)	Run	Peak Power (W/g)	Peak Power (W/g)
1	23	1	2.76	2.40
2	100	1	N/A	14.20
3	150	1	1.56	14.41
4	150	2	N/A	3.65
5	200	1	2.93	14.18
6	200	2	0.79	14.62
7	250	1	7.05	2.94
8	250	2	0.56	14.92
9	300	1	2.25	12.84
10	300	2	0.56	11.85

High Temperature Baking

* Samples usually baked overnight at 300 C under high vacuum to drive off excess oxygen
* Two samples baked at 750 C for 3 hours prior to pressurization
* TPD (temperature programmed desorption) used to study oxygen concentration
* Samples then pressurized to determine effect of baking temperature on peak power of particles

High Temperature Baking



UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

High Temperature Baking

- Most oxygen is driven off at temperatures above 650 C
- Pressurization after baking at theses high temperatures had reduced power generation
- Indicates deactivation of particles at these high temperature bakes
- Optimum temperature for cleaning w/o deactivation

  about 4-500 C

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Metal Hydride	Heat of absorption		Reference
	kJ / mol · H_2	kJ / g · metal	
ZrH_2	106	1.16	R. Griessen, T. Riesterer, in: L. Schlapbach (Ed.), Hydrogen in Intermetallic Compounds I, Springer-Verlag, Berlin, 1988. p. 266
$ZrH_{1.5}$	174	1.43	P. Dantzer, W. Luo, Ted B. Flanagan, And J.D. Clewley, Calorimetrically Measured Enthalpies for the Reaction of Ha (g) with Zr and Zr Alloys, Metallurgical Transactions A, volume 24A, july 1993. p. 1471
$Zr_{0.9}Ti_{0.1}Cr_{1.1}Fe_{0.9}$	32.6	0.18	LG Electronics + KAIST joint research
Nano-Alloy-A	n/a	13.15	Lenuco
Nano-Alloy-B	n/a	19.01	Lenuco

cf. H_2 combustion by O_2 = 10 J/cc

Assume 20cc of H_2 + 5cc of O_2 → 0.2 kJ from 25 cc reactor

Summary of the Nanoparticle Comparison

* Type C has highest gain
* Type B has a higher peak power compared to Type A (W/g)
* Regeneration after runs for Type B is encouraging – relatively consistent peak power output
* Particle A – increased power with increased initial temperature
* Particle B – no clear temperature dependence on peak power
* High temperature baking (750C) causes possible deactivation of particles

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Loaded Nanoparticles composition SIMS measurements

SIMS

- Gold ion beam ionizes the surface of a sample and emits ions that are directed to strike a target
- Evaluates mass of atoms/molecules and creates a spectrum
- Quantitative results are only obtained by comparison between two or more samples

Preliminary remarks on pressurized particles

- The nanoparticles are suspected to have contamination from the stainless pressure vessel
- New elements detection : Ca, Na
  - Possible contamination from environment

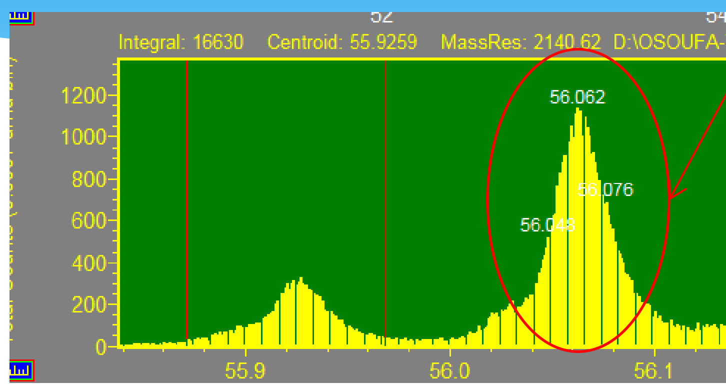
ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Loaded Nanoparticles composition

Stainless steel chamber contamination: Fe, Cr, Ni…

5,85%

6,7%



Noise or hydrocarbonates

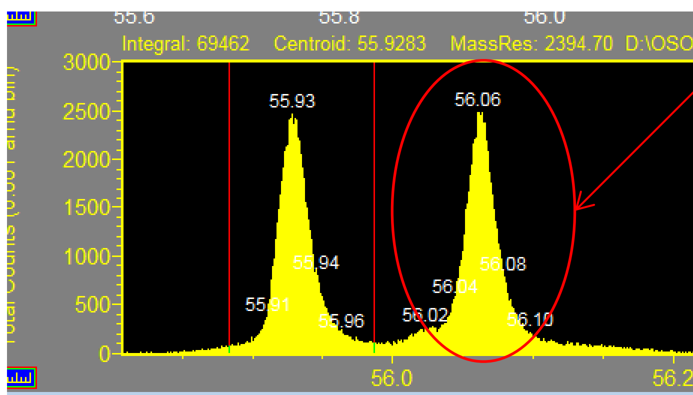
Sample of blank alloys

03/11/13 Control alloy

Increasing of the ratio

12,6%

15,6%



Noise or hydrocarbonates

Sample of pressurized nanoparticles

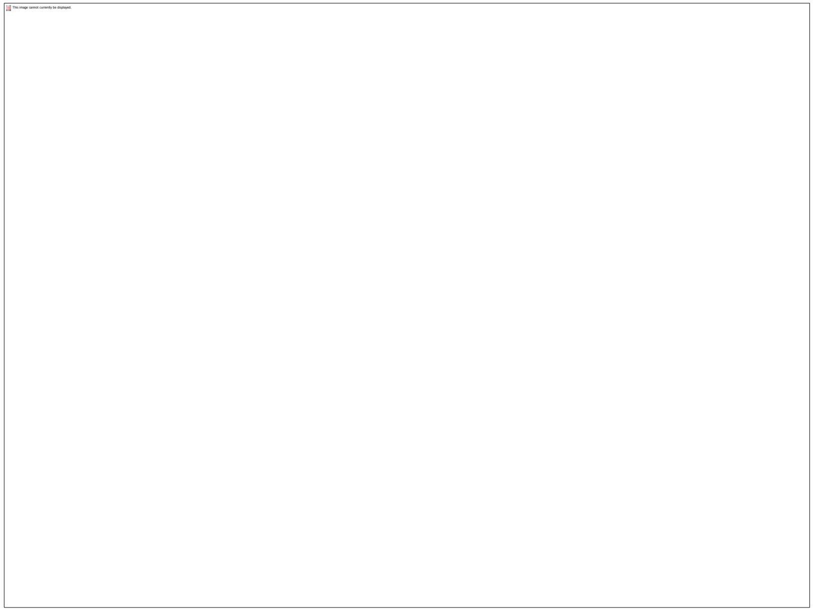
03/11/13 Pressurized sample

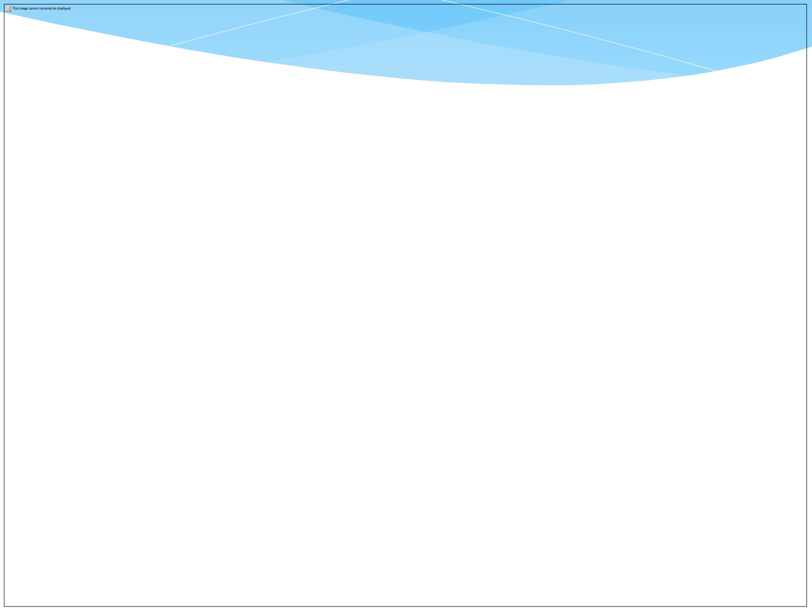
Ratios over main isotope of Palladium

Ratios over main isotope of Zirconium

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Illustration of nanoparticle run time issue: coagulation can occur





SEM image of the nanoparticles A before (left) and after (right) deuterium gas loading experiment

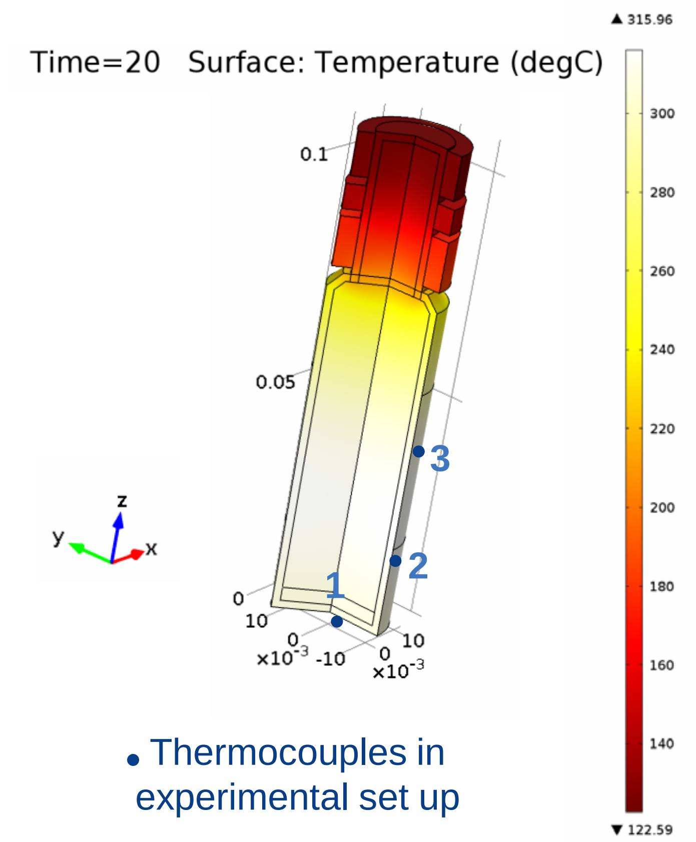
Proposed methods to prevent aglomeration of nanoparticles and allow higher control point temperatures

* Increase surface oxide layer thickness
* Changes in composition
* Embed particles in substrate
* Control reactor temperature profile to avoid hot spots

Heat transfer simulations using Comsol Multiphysics

- Geometrical model of the chamber
- It is being calibrated to determine accurate heat transfer coefficients
- Comsol will give access to internal temperatures field and more accurate values for energy and power generation

Reference simulation



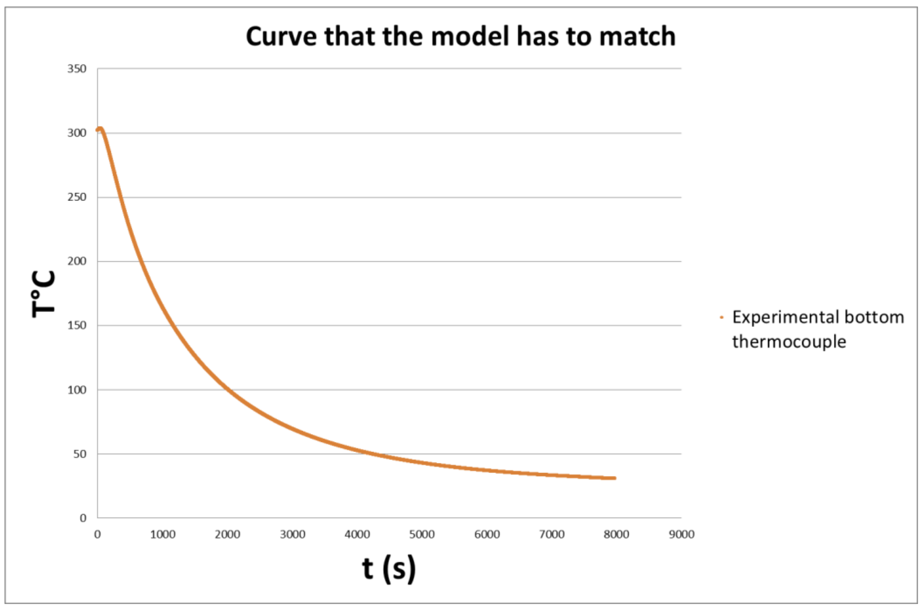
- Thermocouples in experimental set up

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Heat transfer simulations using Comsol Multiphysics

- Goal : Validate the model at many initial conditions
- See Below : Reference cooling process at initial temperature of 300°C

We are on the process to reach a quadratic error between experimental data and simulation of less than 6% for all thermocouples.



Conclusion

* Experimental results with cluster loaded materials are very encouraging
* Work concentrating on run time and control issues is needed to develop a commercial unit
* Vision and goal – distributed power units in wide use for co-generation.
* Negotiating with several companies for early demonstration units.

Thanks for your attention

* George H. Miley
* Erik Ziehm, Tapan Patel, Anais Osouf,
* Dr. Kyu-Jung Kim, Bert Stunkard
* University of Illinois
* Champaign IL, 61821 USA
* ghmiley@illinois.edu
* 217-333-3772

For more information:

- *Recent results from gas loaded nanoparticle-type cluster power units*. Patel, T., Miley, G., Osouf, A., Stunkard, B., Kyu-Jung, K., & Ziehm, E. (2013, July). Poster session. ICCF-18, University of Missouri, Columbia.
- *Study of Composition of Nanoparticles during Gas Loaded LENR Power Cell Operation*. Osouf, A., Miley, G., Patel, T., Stunkard, B., Kyu-Jung, K., & Ziehm, E (2013, July). Poster session. ICCF-18, University of Missouri, Columbia.