What Low Energy Nuclear Reactions (LENR) Are and Why They are not Widely Publicized

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I Background about Cold Fusion

II Key Excess Heat and Helium Electrolytic Experiments

III Important Gas-Loading Experiments

IV Evidence for Transmutations

V Why Low Energy Nuclear Reactions (LENR) are not more widely publicized

VI Theoretical Modeling based on Conventional Physics

The Cold Fusion Debacle

Martin Fleischmann and Stanley Pons (pictured) were chemists at the University of Utah who, starting in 1980, spent $100,000 of their own money to pay for peculiar electrochemical research. *Their experiments were simple*: they bathed a metal electrode in a test tube filled with "heavy water," which contains deuterium, an isotope of hydrogen. After letting the metal electrode absorb a great deal of deuterium, the researchers passed an electric current through it. Fleischmann and Pons said their experiment generated heat, which they interpreted as a sign that the deuterium nuclei had fused together.

From:http://www.tecsoc.org/pubs/history/2001/mar23.htm

- Their results s were difficult to reproduce and were almost universally viewed to be wrong.
- We now know that they were actually right
- In fact, their experiments were not simple. The name “Cold Fusion” is wrong.

A More Complete Description (Wikepedia)

From: http://en.wikipedia.org/wiki/Cold_fusion#History

- Scores of laboratories in the United States and abroad attempted to repeat the experiments. A few initially reported success, but most failed to validate the results; Nathan Lewis, professor of Chemistry at the California Institute of Technology, led one of the most ambitious validation efforts, trying many variations on the experiment without success, while CERN physicist Douglas R. O. Morrison said that "essentially all" attempts in Western Europe had failed.[28]

- Even those reporting success had difficulty reproducing Fleischmann and Pons' results.[29] One of the more prominent reports of success came from a group at the Georgia Institute of Technology, which observed neutron production.[30] The Georgia Tech group later retracted their announcement.[31] Another team, headed by Robert Huggins at Stanford University also reported early success,[32] but it was called into question by a colleague who reviewed his work.[5] For weeks, competing claims, counterclaims and suggested explanations kept what was referred to as "cold fusion" or "fusion confusion" in the news.[33]In April 1989, Fleischmann and Pons published a "preliminary note" in the *Journal of Electroanalytical Chemistry*.[20]

- This paper notably showed a gamma peak without its corresponding Compton edge, which indicated they had made a mistake in claiming evidence of fusion byproducts.[34][35] The preliminary note was followed up a year later with a much longer paper that went into details of calorimetry but did not include any nuclear measurements.[21]In May 1989, the American Physical Society held a session on cold fusion, at which were heard many reports of experiments that failed to produce evidence of cold fusion. At the end of the session, eight of the nine leading speakers stated they considered the initial Fleischmann and Pons claim dead with the ninth abstaining.[28] In July and November 1989, *Nature* published papers critical of cold fusion claims.[36][37] Negative results were also published in several scientific journals including *Science*, *Physical Review Letters*, and *Physical Review C* (nuclear physics).[38]

SIMPLE CONCEPTUAL DIAGRAM

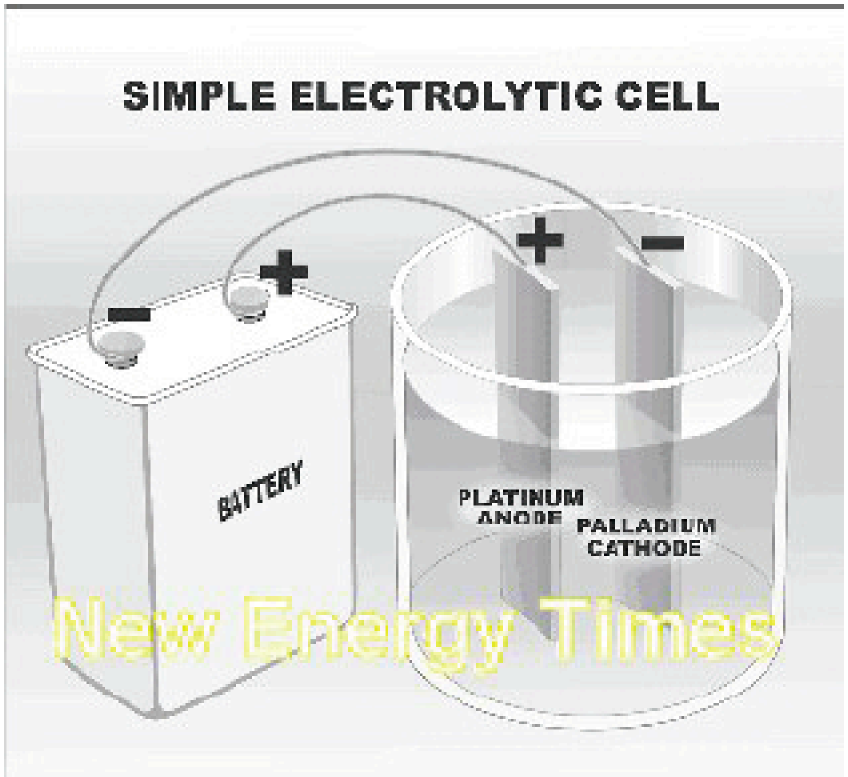
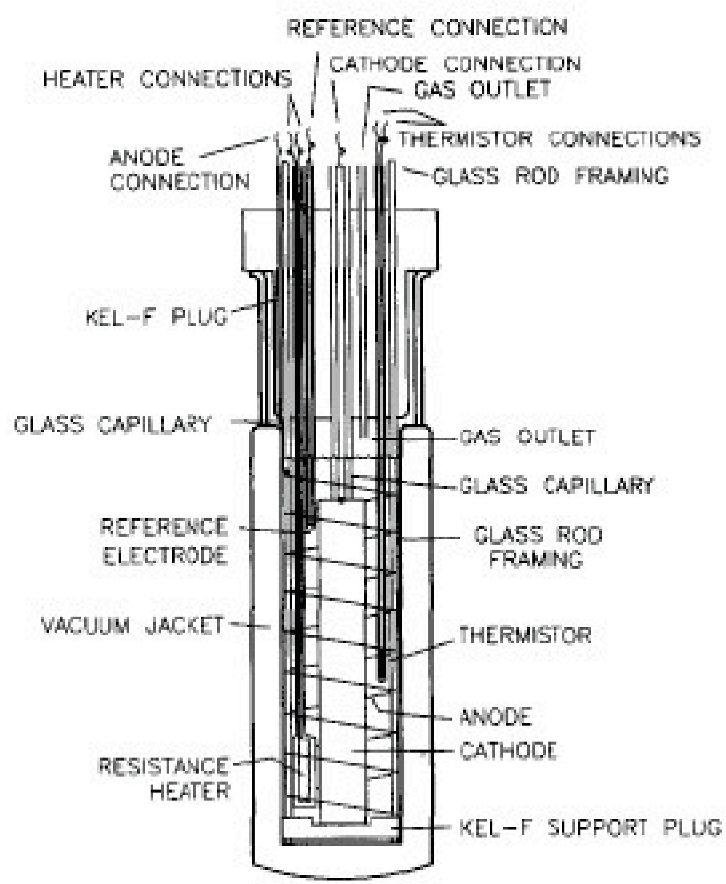


Figure 1-2. Simple Electrolytic Cell.
(Drawing by Craig Erlick)

SCHEMATIC DIAGRAM



Original diagram from 1990 Fleischmann-Pons seminal paper.

The Fleischmann-Pons Cold Fusion Method

Excerpt from *The Rebirth of Cold Fusion Real Science, Real Hope, Real Energy*
By Steven B. Krivit and Nadine Winocur, Psy.D

Excess Heat (Constant Voltage) vs Time (Fleischmann-Pons Experiments)

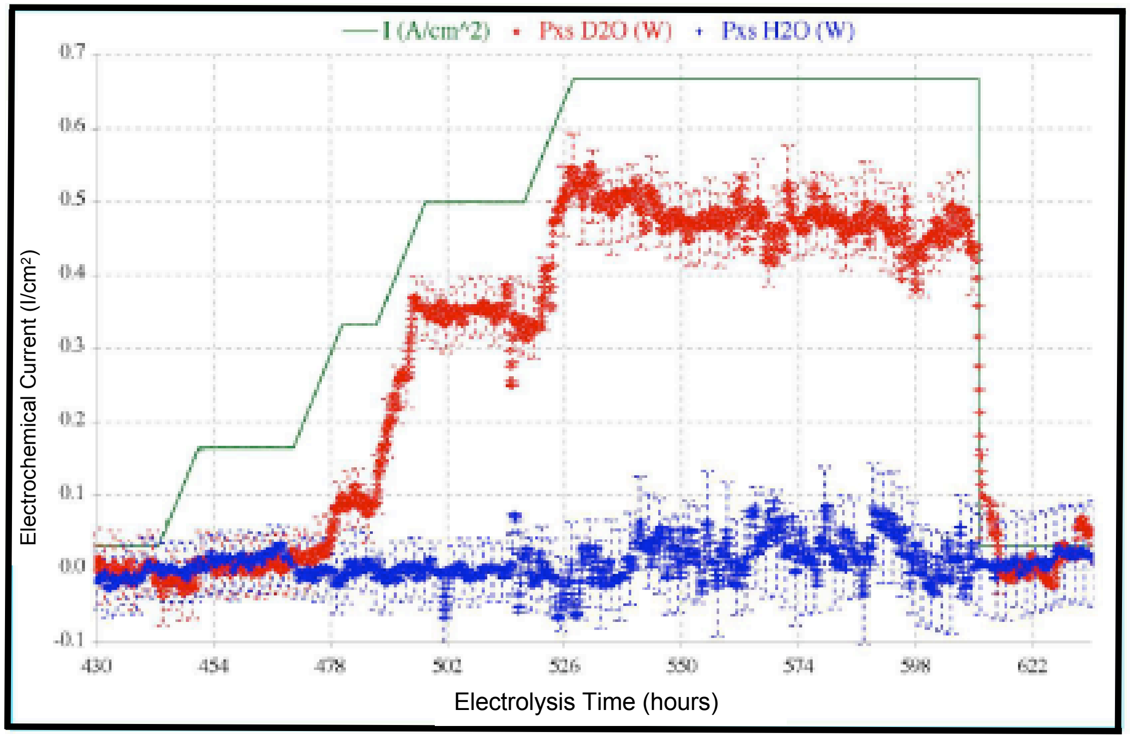
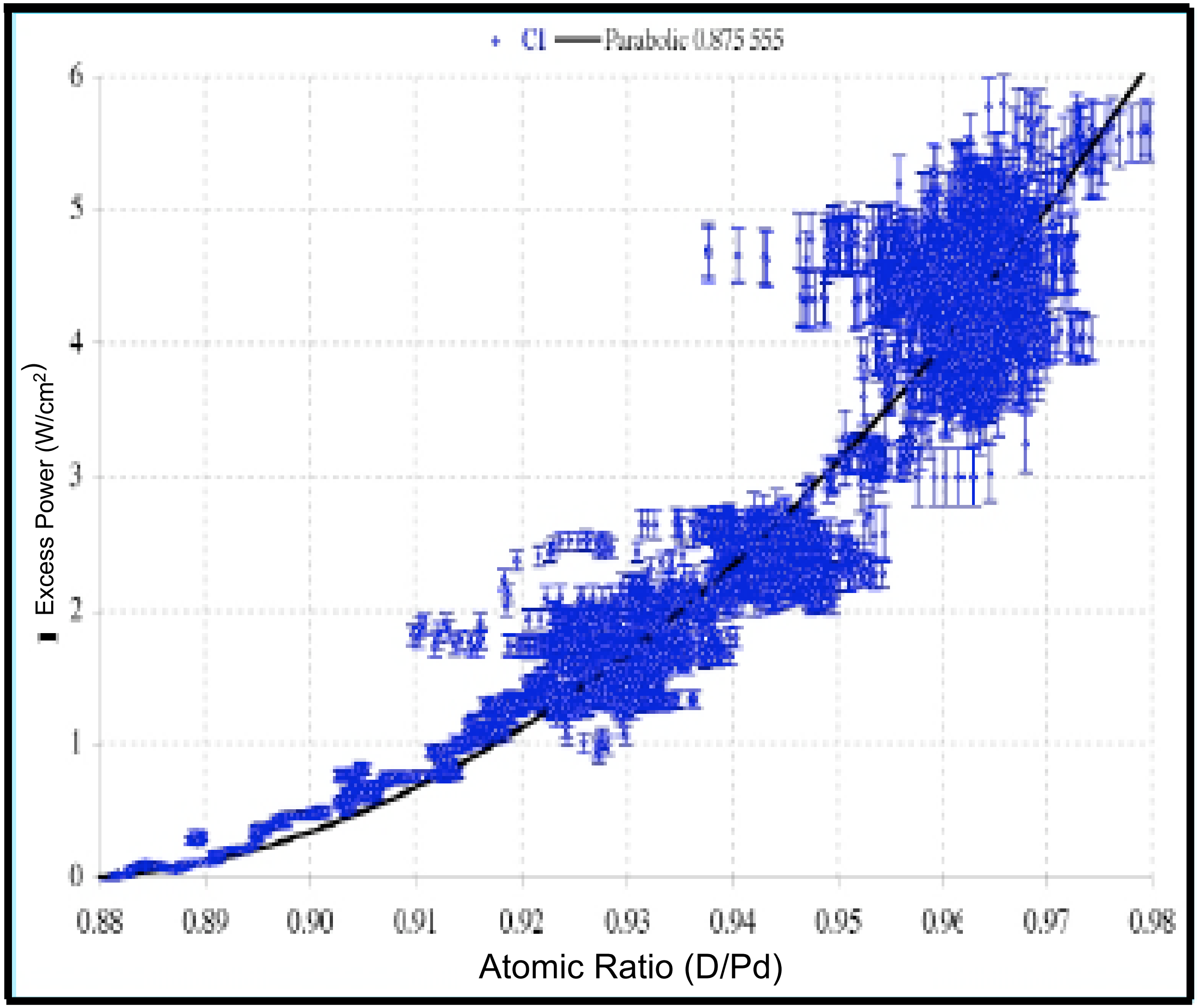


Figure 1. Excess power in Fleischmann-Pons experiments as a function of time in twin cells and calorimeters, driven with a common current, one with heavy water and one with light water.

- "Cold Fusion" requires long "incubation time"—Key reason for failures

"Cold Fusion" Requires High-loading: Key reason for Failures



McKubre et al, from Hagelstein et al (DOE Re-Review)

http://www.lenr-canr.org/acrobat/Hagelsteinnewphysica.pdf

Violante, V., et al. *Material Science on Pd-D System to Study the Occurrence of Excess Power*. in *ICCF-14 International Conference on Condensed Matter Nuclear Science*. 2008. Washington, DC.

Material Science on Pd-D System to Study the Occurrence of Excess Power

V. Violante [1], F. Sarto [1], E. Castagna [1], M. Sansovini [1], S. Lecci [1], D. L. Knies [2], K. S. Grabowski [2], and G. K. Hubler [2]

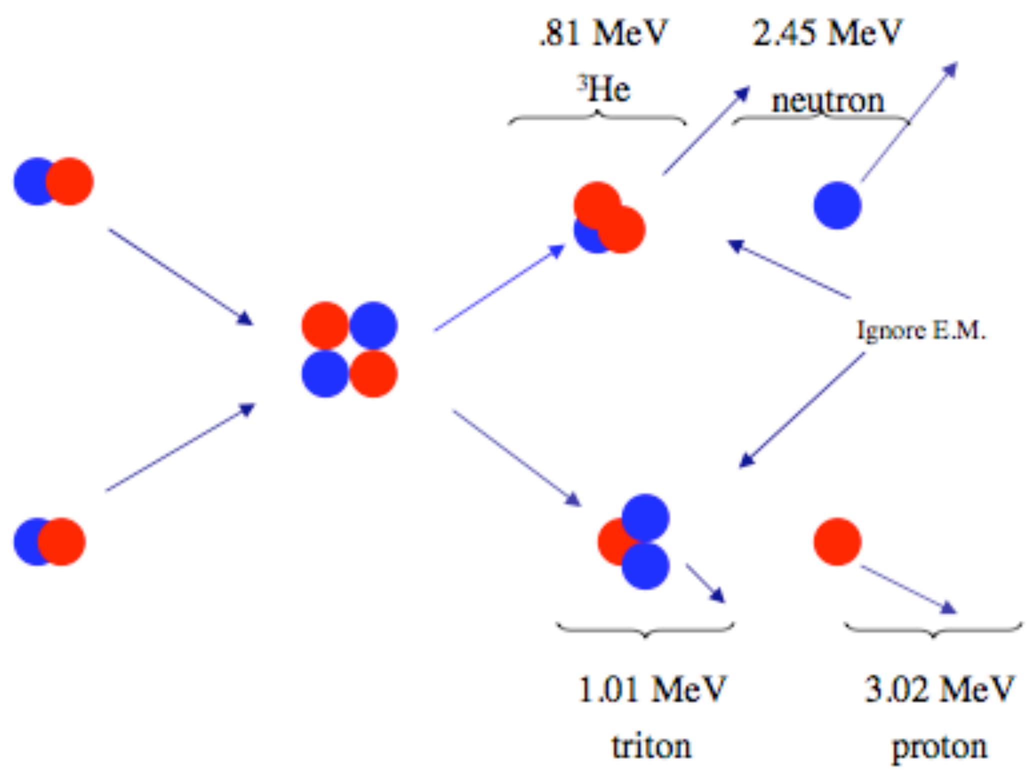
[1] *ENEA Frascati Research Center, Frascati (Rome) 00044 Italy*

[2] *Naval Research Laboratory, Washington DC 20375 USA*

Abstract

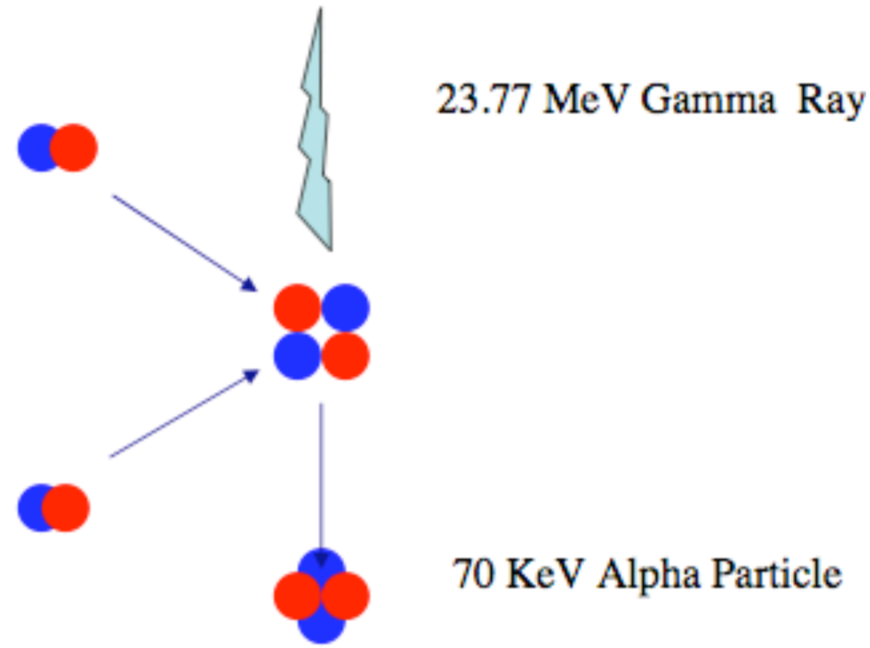
A recent joint work [1] identified the crucial role of material science in improving control of the Pd-D system to enhance the production of excess power during electrochemical loading of palladium foils with deuterium. Very high reproducibility, close to 100%, in loading Pd up to D/Pd ~1 (atomic fraction) was achieved. High loading about the threshold value of 0.9 is considered necessary to achieve the effect. This work demonstrated it is necessary but not sufficient. As a consequence, the focus of our research moved to the material properties of cathodes, especially surface characteristics, and an effort to correlate these properties with cathode performance during electrolysis. This paper describes the material properties examined that appear to produce excess heat.

Facts About Conventional Fusion



- Electromagnetic Interaction (EMI) can be ignored.
- Static, Coulomb barrier applies

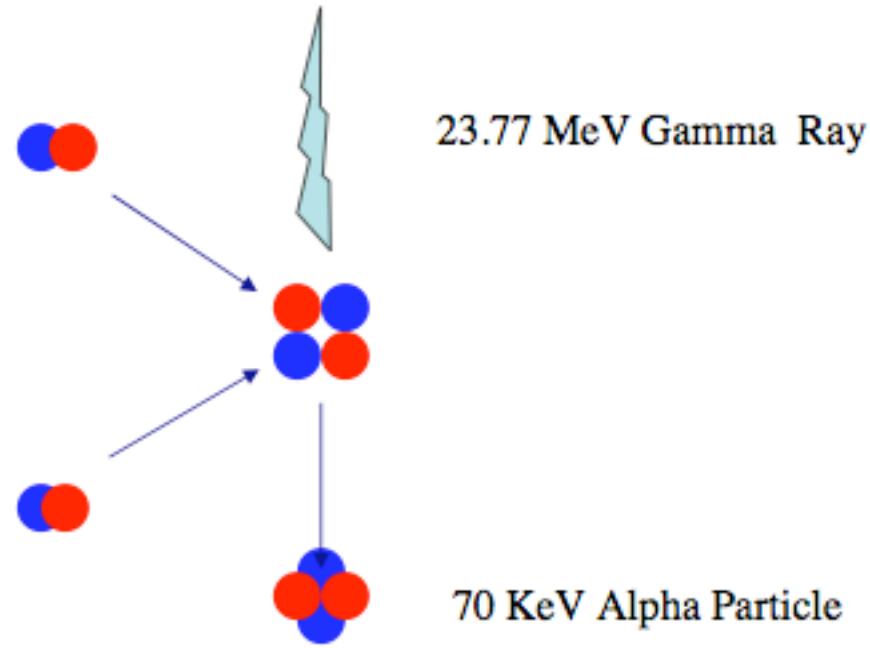
Key Limitation of "Conventional" Nuclear Fusion Theory



- "Secret, 'Rare' Reaction": $d+d \rightarrow {}^4He+\gamma$
- Common assumption: energy release too large
- Assumption is not right. Reaction is Rare because:

  * Reaction involves EMI

Additional Facts About Additional Reaction



- Rate of "Secret Reaction" is 10^7 smaller than other reactions
- Not cited in conventional fusion literature for this reason
- $d+d \longrightarrow {}^4He + \gamma$ is rare, but reverse reaction ${}^4He + \gamma \longrightarrow d+d$ is well-known
- ${}^4He + \gamma \longrightarrow d+d$ teaches us that: In $d+d \longrightarrow {}^4He + \gamma$,
    - ❖ Simplified Coulomb Barrier tunnelling does not apply.
    - ❖ Far from reaction, EMI required: d+d must be prepared appropriately

Historical Note about Importance of EMI in LENR

- Preparata and Schwinger did not know about

$$^{4}\mathrm{He} + \gamma \rightarrow \mathrm{d+d}$$

- Both believed EMI was important, either implicitly (in the case of Schwinger) or explicitly (in the case of Preparata)

Wrong Intuitive Picture has resulted from not Including EMI in $d+d \to {}^4He+\gamma$

- Because all d-d fusion reactions conserve isospin, it has been widely assumed that the dynamics is driven by the strong force interaction (SFI), NOT electromagnetic interaction (EMI)
- Major source of confusion is the assumption that the strong force dictates both the dynamics and the available energy states and transitions
- True for the conventional reactions but not for $d+d \to {}^4He+\gamma$
- Thus, most nuclear physicists assume: 1. EMI is static; 2. Dominant reactions have smallest changes in incident kinetic energy (T); and (because of 2), $d+d \to {}^4He+\gamma$ suppressed.

Helium-4 in Cold Fusion

- Dominant Reaction: $d + d \rightarrow {}^4He + 23.8$ **MeV (Involving Many Particles)**

- "Officially Announced" Through Multi-Laboratory, Decade Long ONR Study (2002)

THERMAL AND NUCLEAR ASPECTS OF THE Pd/D2O SYSTEM
Vol. 1: A DECADE OF RESEARCH AT NAVY LABORATORIES
SPAWAR Technical Report 1862 (Naval Space Warfare Systems Center, San Diego)

Eds. P.A. Mosier-Boss and S. Szpak

More Details about Technical Report 1862

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http://www.lenr-canr.org/acrobat/MosierBossthermaland.pdf

- Report inspired New Scientist Article, partially responsible for DOE Re-Review (2004)

Arata-Zhang (A&Z) Excess Heat/Helium Program

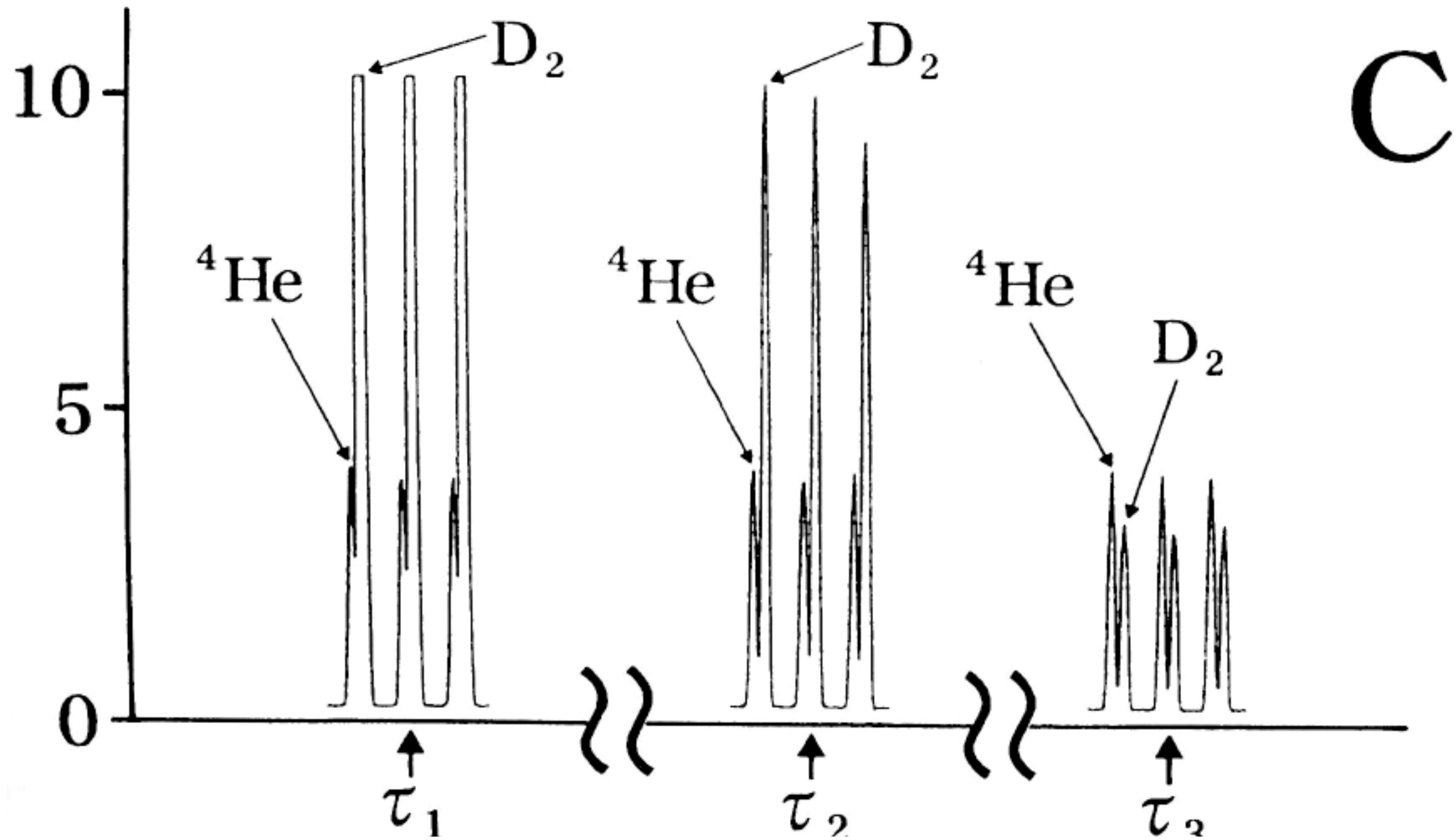
Four features characterize early Arata-Zhang work:

- The DS-Cathode, which uses a Pd cylinder with welded stainless steel end plates and filled with nanoPd in the form of Pd-black
- DS-cathode means "double structure" cathode
- Outer cylindrical wall made of Pd metal and an interior filled with Pd-black
- Cylinder ends made of stainless steel. Interior Pd-black evacuated and sealed-off before use

Protocol shows nanoPd (Pd-Black) absorbs H differently than bulk Pd does

Water flow calorimeter is used that has long term stability

A & Z Use Getter Pumping to Help Measure ^4He



- In 2000, A&Z reported finding $^4He/^3He$=800
  (This ratio is ~2000 greater than in air)

Most Accurate Evidence for $d + d \rightarrow {}^4He + 23.8\ MeV$
(Helium Retrieved from Interior of Metal)

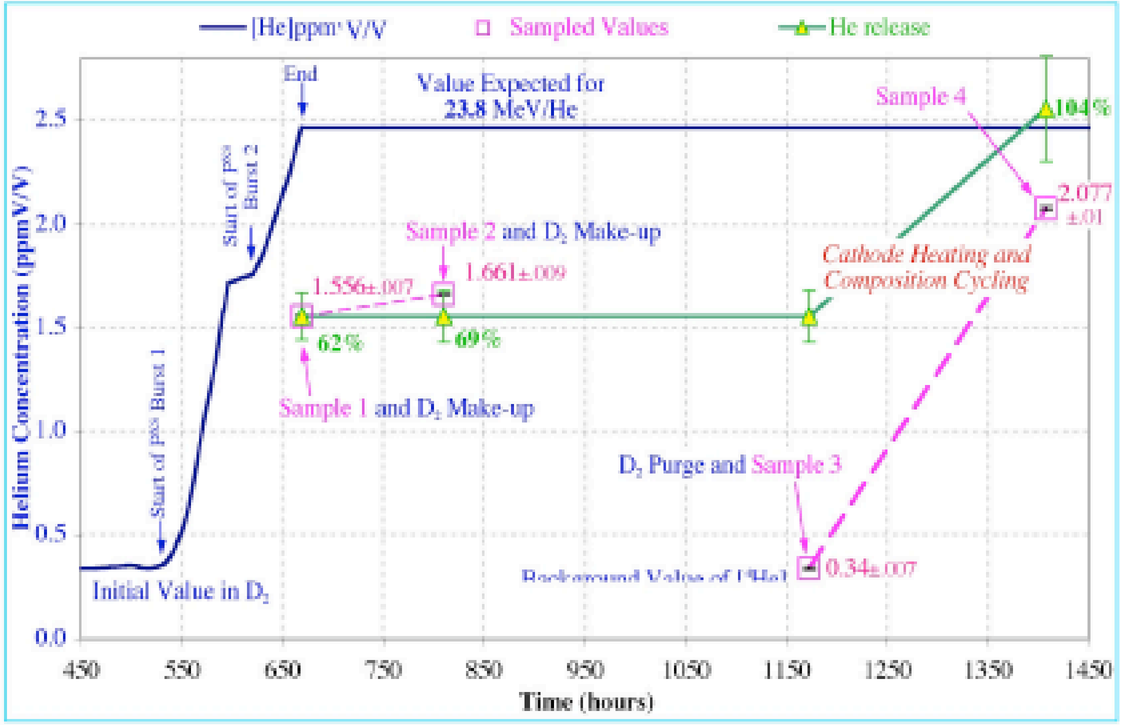


Figure 7. Results for ^{4}He measurements associated with the excess heat results presented in Figure 5, as discussed in the text. The concentration of helium and gas sampling times are indicated by squares, and the fraction of that expected for a 23.8 MeV/^{4}He atom by triangles.

McKubre et al, from Hagelstein et al (DOE Re-Review)

http://www.lenr-canr.org/acrobat/Hagelsteinnewphysica.pdf

A&Z (2002)

- First tests with ZrO_2 + nanoPd catalyst
  - Catalyst invented by Institute for Materials Research, Tohoku U.*
- A-Z absorption protocol shows high absorption
- Electrolysis DS-cathode study shows 3 weeks @ 10 W excess heat

The New Catalyst

- Yamaura et al. invent ZrO_2 + nano Pd catalyst
- Evaluation protocol shows longer "zero-pressure" period than Pd-black
- Achieves a H/Pd ratio = ~ 3 at 100 atm
- Photomicrograph shows Pd nanocrystals embedded in ZrO_2
- Prevents contact-induced crystal growth

* Yamaura et al., *J. Mater. Res.* **17**. 1329 (2002).

A & Z Oxidized Nano-powders

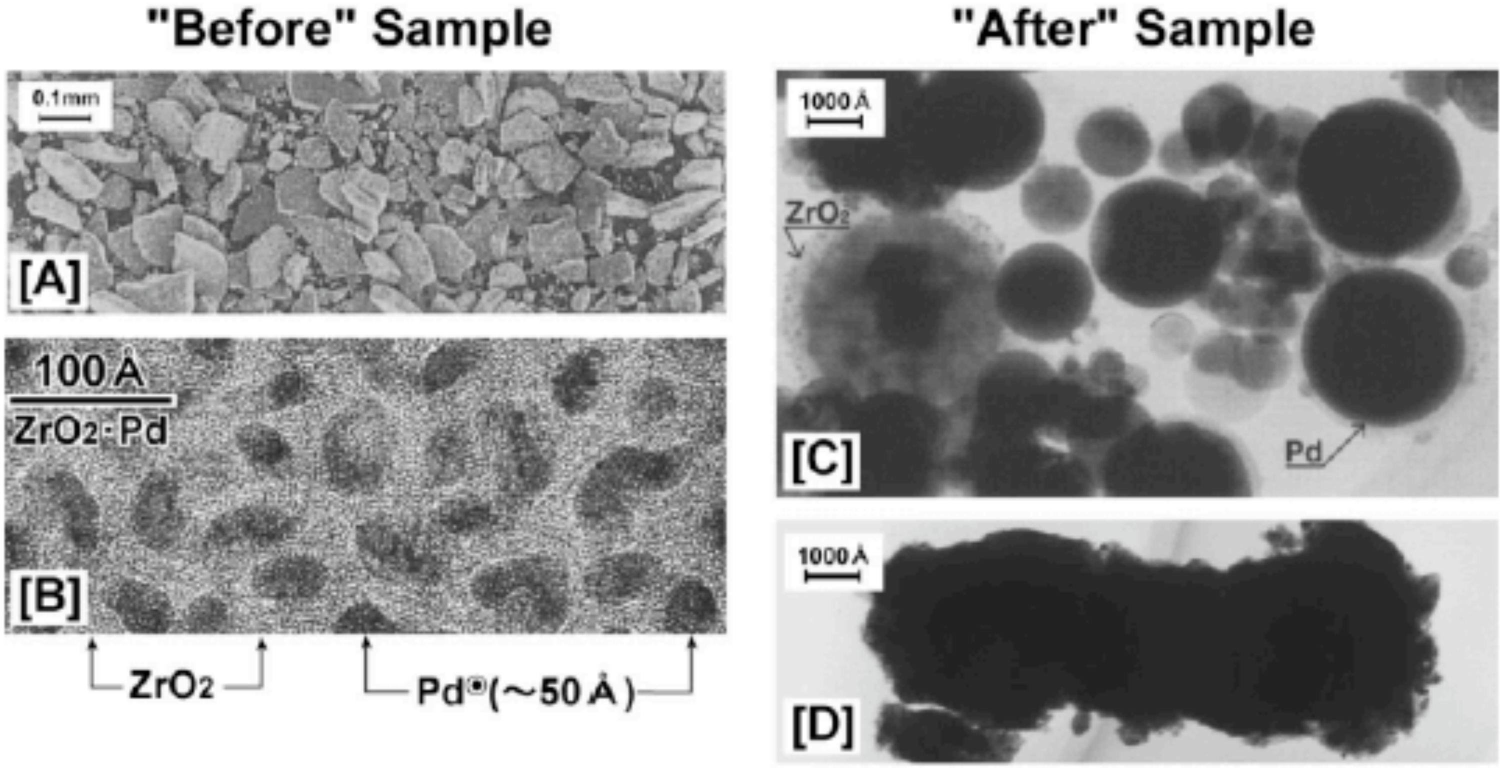
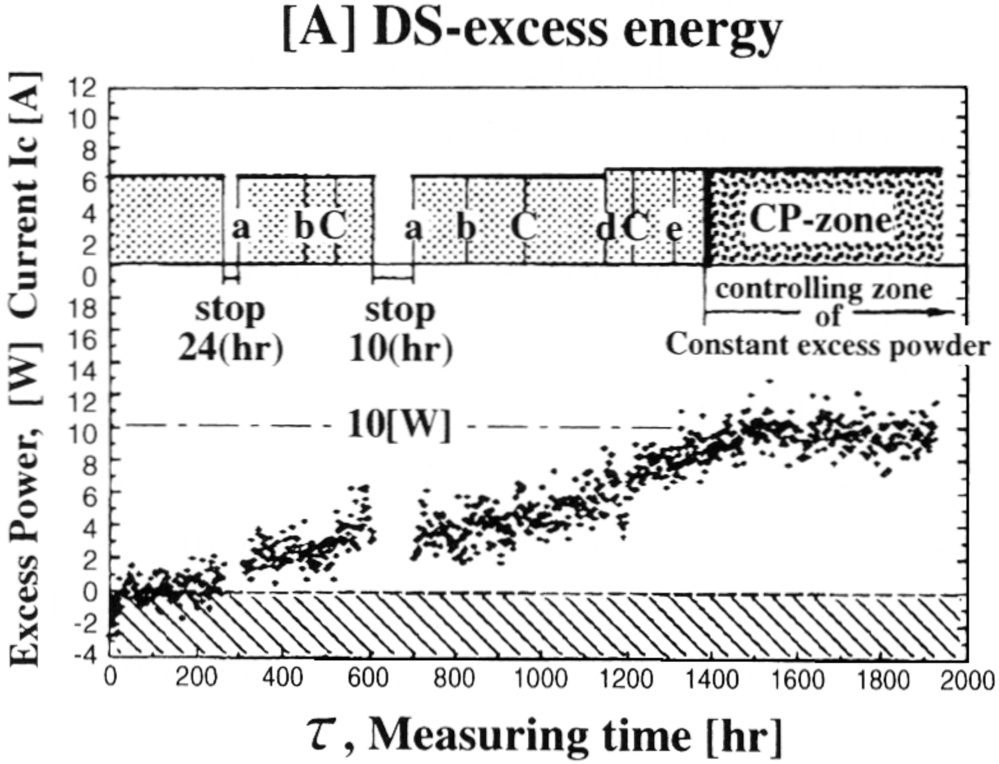


Fig. 6 Photomicrograph [A] and electron micrographs ([B], [C], [D]) of characteristics and its change of the sample powder ($ZrO_2 \cdot Pd^{\circledcirc}$) using laser welding nuclear fusion system.

10W Excess Heat for 3 Weeks



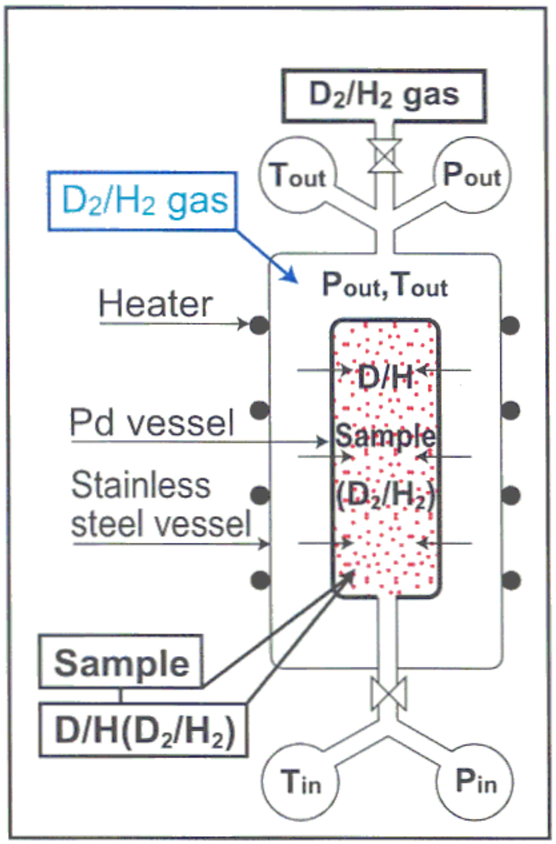
Integrated cold fusion power = ~ 70% best hot fusion run.

Gas Loading: A&Z (2005)

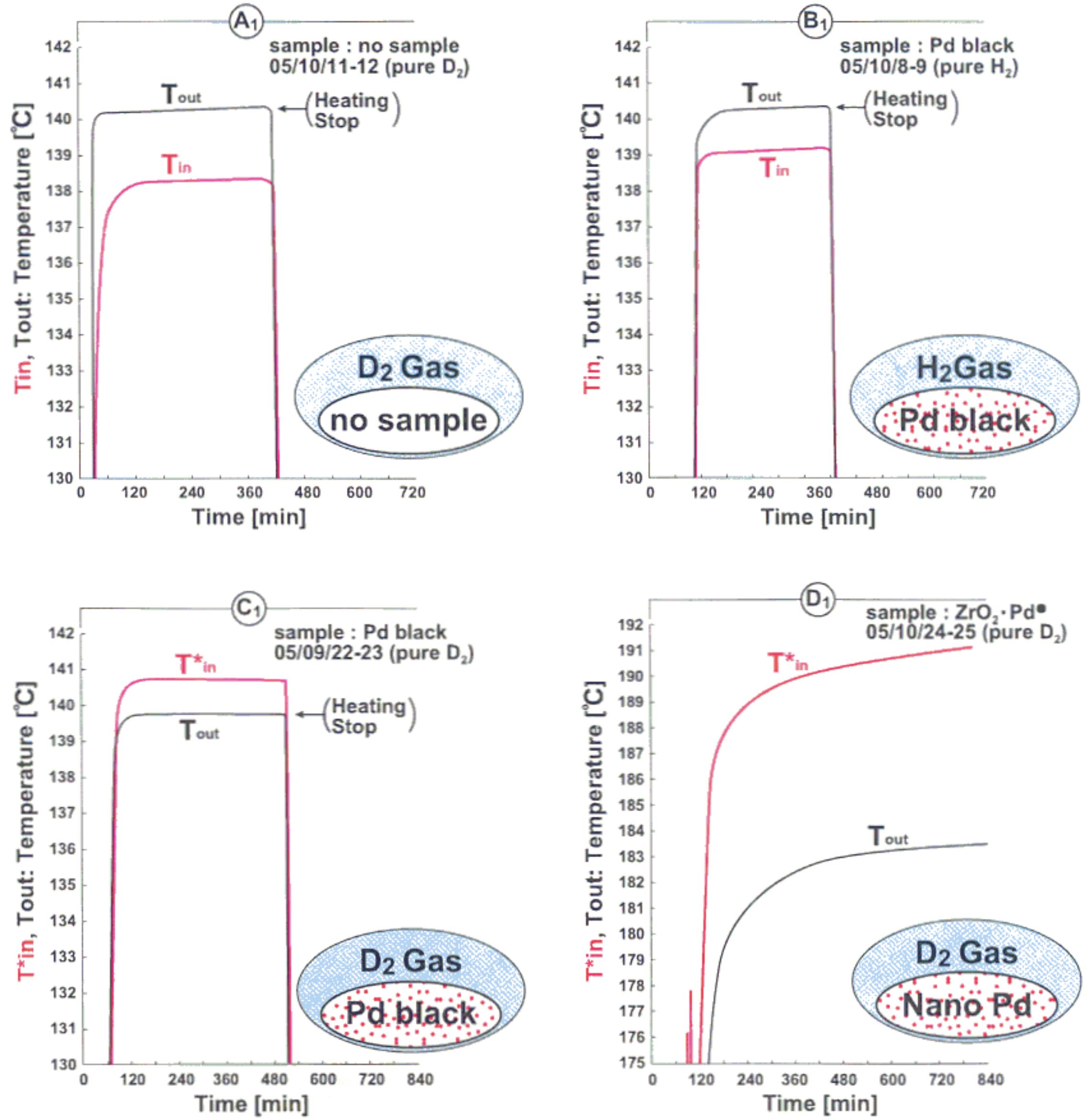
Gas loading replaces electrolysis. The DS-Cathode becomes the inner–vessel of a double cylinder reactor. Four tests were carried out using a reactor pre-heated to 141°C:

1. D_2 flows into volume between outer and inner vessels, no catalyst
2. H_2 flows into volume between outer and inner vessels, uses Pd–black: $T_{out} > T_{in}$
3. D_2 flows into volume between outer and inner vessels, uses Pd–black: $T_{in} > T_{out}$
4. D_2 flows into volume between outer and inner vessels, uses ZrO_2 + nanoPd catalyst: $T_{in} > T_{out}$ & $T_{in} \rightarrow 191^oC$

DS-Reactor



D2/H2 gas
Tout
Pout
D2/H2 gas
Pout, Tout
Heater
D/H
Pd vessel
Sample
Stainless steel vessel
(D2/H2)
Sample
D/H(D2/H2)
Tin
Pin

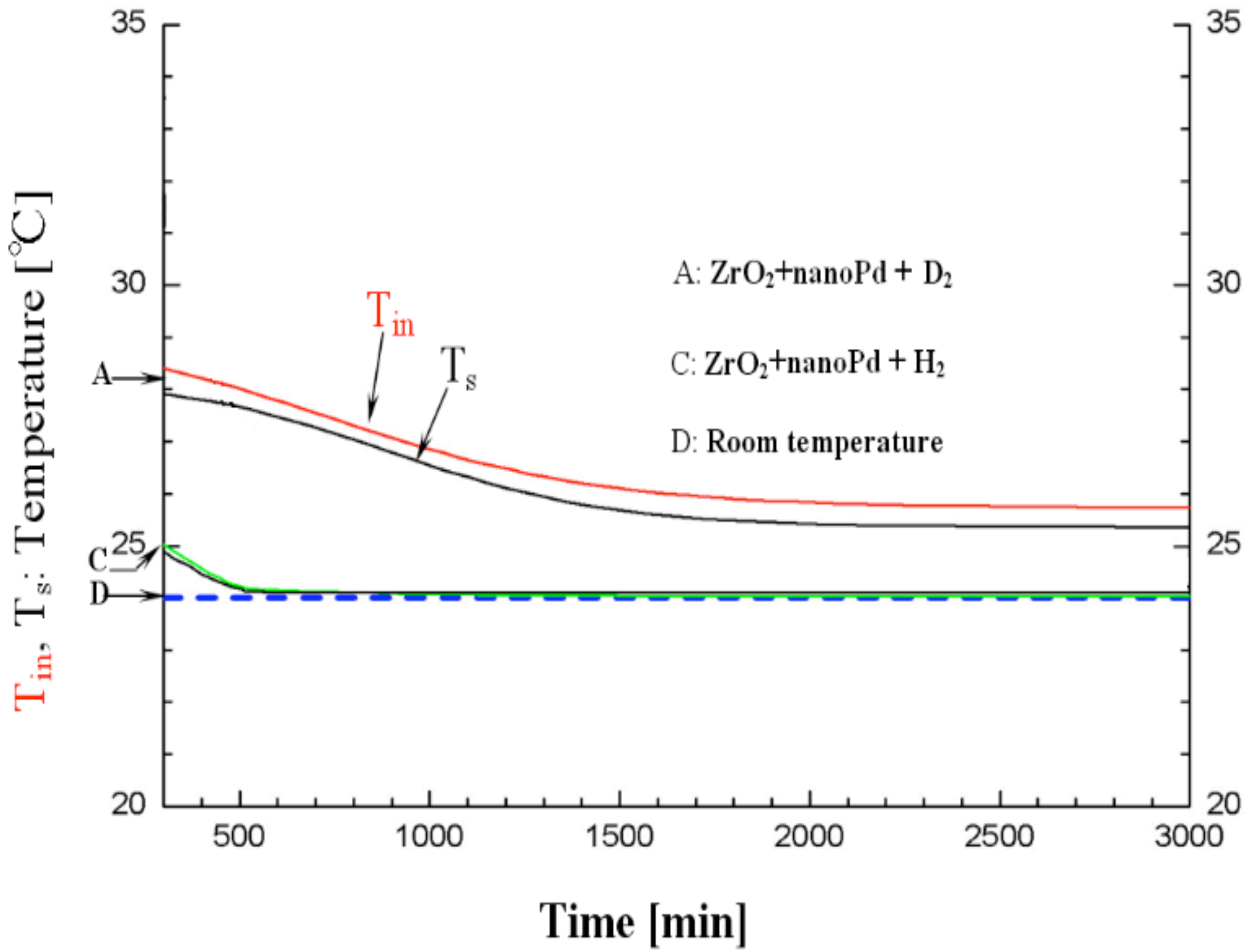


A1
sample : no sample
05/10/11-12 (pure D2)
Tout
Tin
Heating Stop
D2 Gas
no sample
Tin, Tout: Temperature [°C]
Time [min]
B1
sample : Pd black
05/10/8-9 (pure H2)
Tout
Tin
Heating Stop
H2Gas
Pd black
Tin, Tout: Temperature [°C]
Time [min]
C1
sample : Pd black
05/09/22-23 (pure D2)
T*in
Tout
Heating Stop
D2 Gas
Pd black
T*in, Tout: Temperature [°C]
Time [min]
D1
sample : ZrO2·Pd●
05/10/24-25 (pure D2)
T*in
Tout
D2 Gas
Nano Pd
T*in, Tout: Temperature [°C]
Time [min]

Heat with Zero Input Power: A-Z (2008)

- A-Z replace double cylinder reactor with single stainless steel vessel sealed off at both ends
- Contains 7 grams of ZrO_2 + nanoPd catalyst
- Zero electrolysis and zero heater power used in the experiment
- Catalyst bed evacuated
- Pd-filtered D_2 inflow gas applied to gradually raise reactor vessel pressure towards 100 atm

Heat Flow with Zero Input Energy



^4He in Experiments Involving D_2 Gas Loaded into Pd

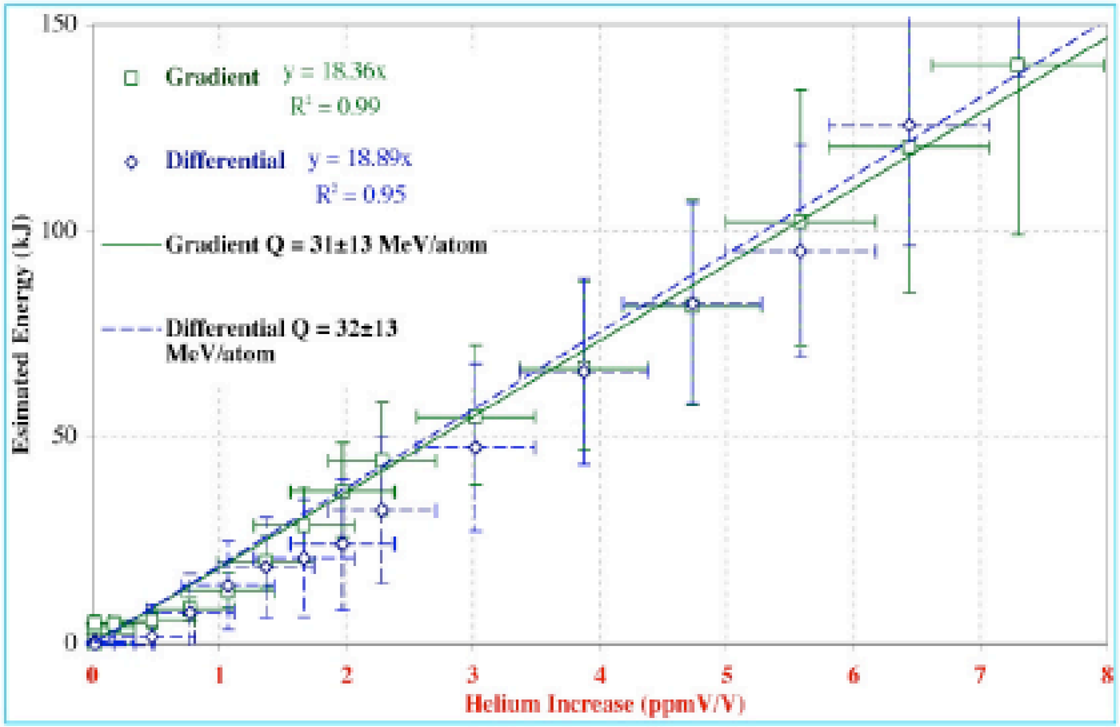
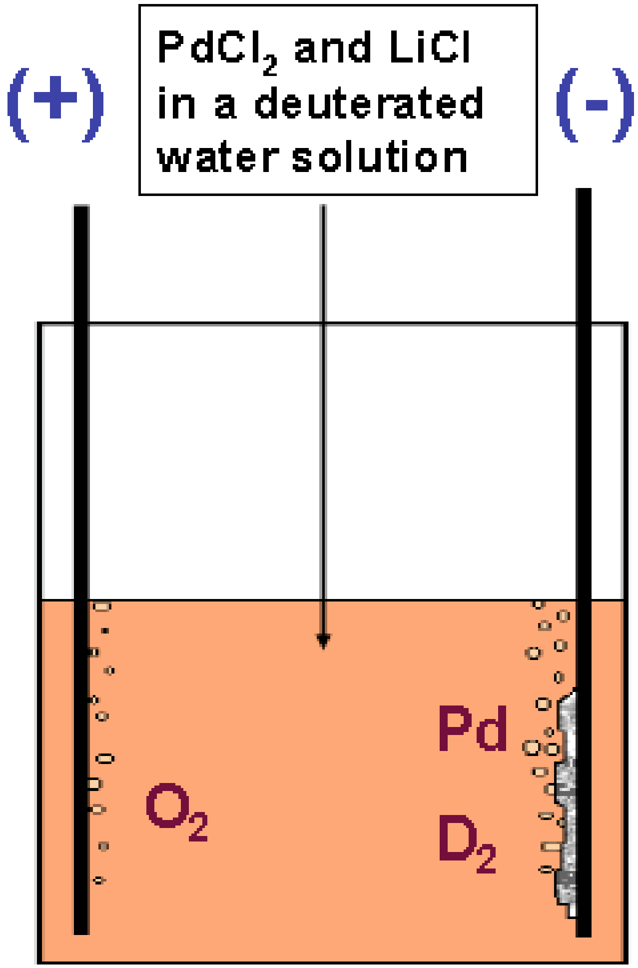


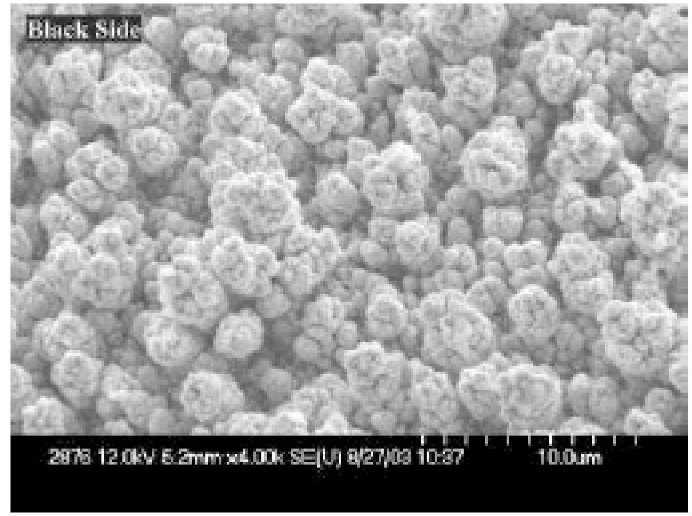
Figure 6. Excess energy determined by gradient (boxes) and differential (diamonds) calorimetric methods plotted against the increase in ^4He concentration in a metal-sealed helium leak-tight vessel. The experiment was performed by heating palladium on carbon hydrogenation catalyst materials to ~190° C in ~3 atmospheres of D_2 gas pressure (see Appendix B).

McKubre et al, from Hagelstein et al (DOE Re-Review)

http://www.lenr-canr.org/acrobat/Hagelsteinnewphysica.pdf

Pd/D Co-Deposition





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

$$Pd^{2+} + 2\,e^{-} \rightarrow Pd^{0}$$

$$D_2O + e^{-} \rightarrow D^{0} + OD^{-}$$

The result is metallic Pd is deposited in the presence of evolving D_2

Szpak, Mosier-Boss, Gordon

Summary of Results Obtained Using Pd-D Co-Deposition

(As of 2007)

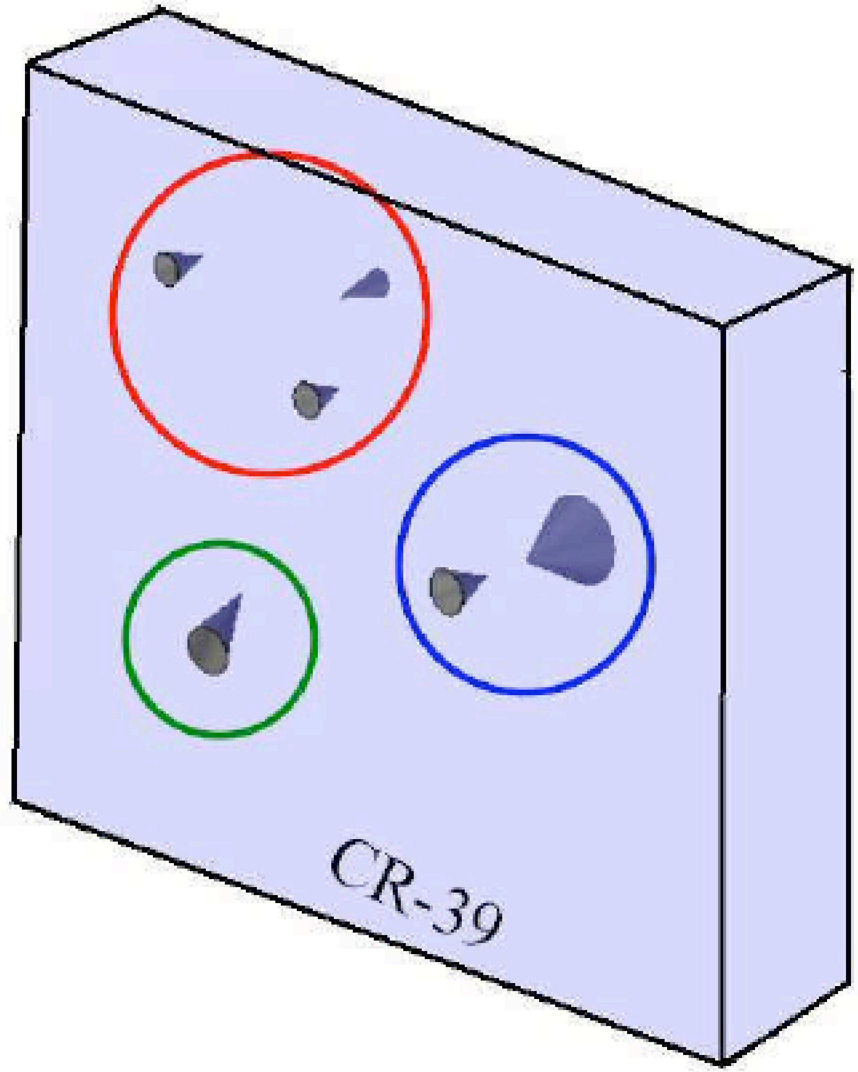
- **Excess Enthalpy Generation**
  Thermochimica Acta, Vol. 410, pp. 101-107 (2004)
- **Formation of 'Hot Spots'**
  Il Nuovo Cimento, Vol 112A, pp. 577-585 (1999)
- **Emission of Low Intensity Radiation**
  Physics Letters A, Vol. 210, pp. 382-390 (1996)
- **Tritium Production**
  Fusion Technology, Vol. 33, pp.38-51 (1998)
- **E-Field Morphology Changes**
  J. Electroanal. Chem., Vol. 580, pp. 284-290 (2005)
- **Presence of New Elements in Association with the Morphology Changes**
  Naturwissenshaften, Vol. 92, pp. 394-397 (2005)

Particle Detection Using CR-39

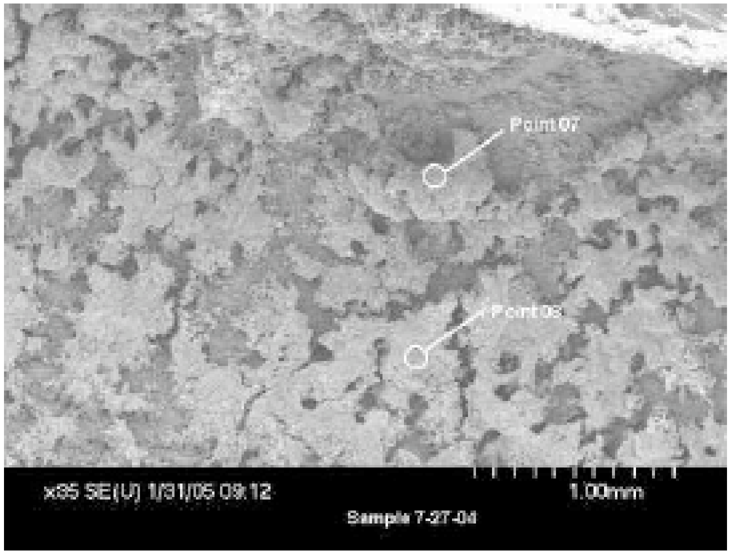
• CR-39, polyallyldiglycol carbonate polymer, is widely used as a solid state nuclear track detector

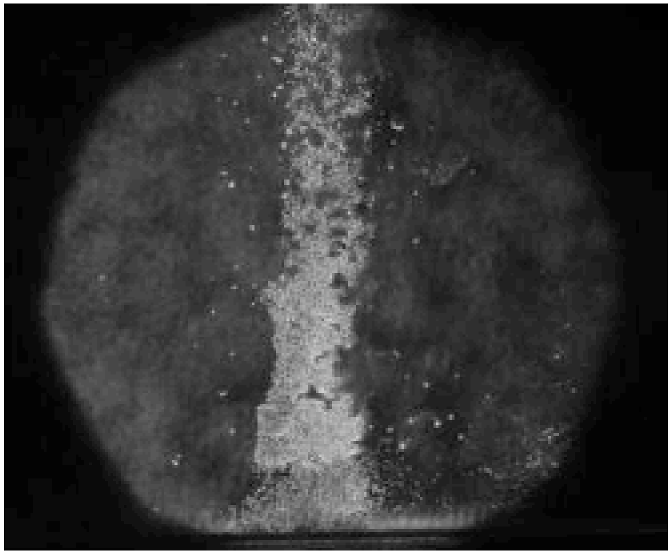
•When traversing a plastic material, charged particles create along their ionization track a region that is more sensitive to chemical etching than the rest of the bulk

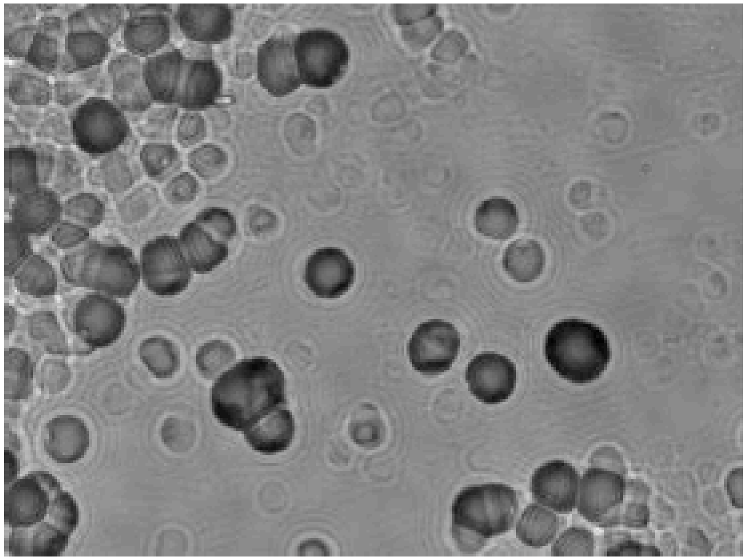
•After treatment with an etching agent, tracks remain as holes or pits and their size and shape can be measured.

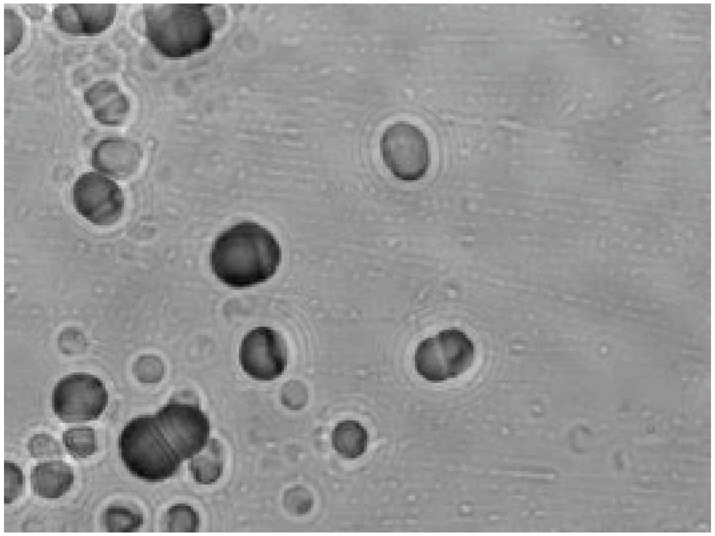


Ag wire/Pd/D in Magnetic Field









Conclusions

- Pits in the CR-39 are obtained during a Pd/D co-deposition experiment
  - Pits are dark with bright points of light at their centers (true of nuclear generated pits)
  - Features due to background are small, bright, shallow, often irregularly shaped, and show no contrast
  - Observe double and triple pits (result from reactions that emit two or three particles of similar mass and energy)
- Pits are not due to radioactive contamination or to the impingement of D_2 gas bubbles on the surface of the CR-39
- 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
- No pits are obtained by replacing $PdCl_2$ with $CuCl_2$
- Pits are observed behind the CR-39 detector that are caused by energetic particles or knock-ons created by neutral particles
- Great variability in different brands of CR-39 as well as variability with different batches

EXCESS HEAT IN ELECTROLYSIS EXPERIMENTS AT ENERGETICS TECHNOLOGIES

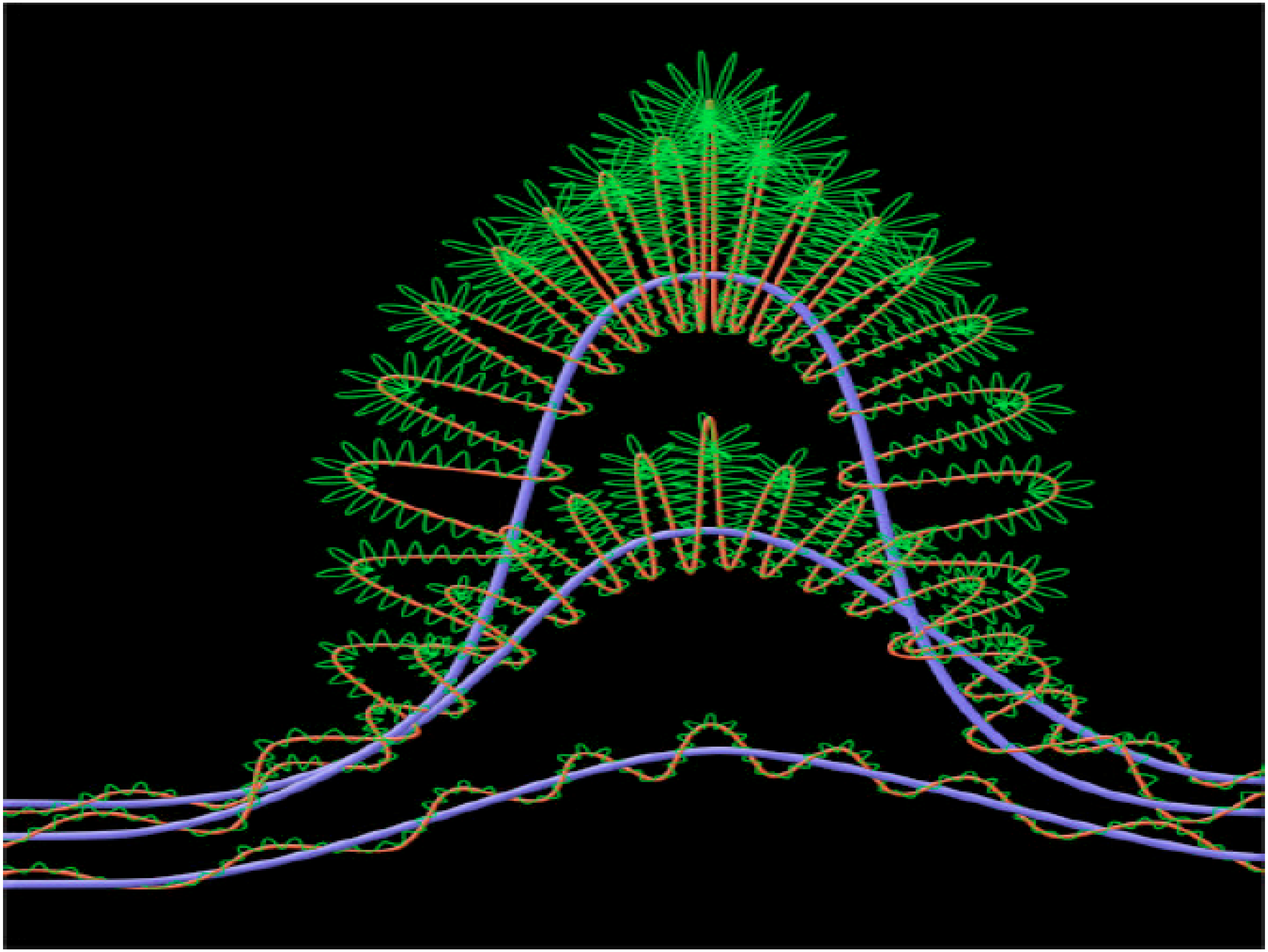
I. Dardik, T. Zilov, H. Branover, A. El-Boher, E. Greenspan, B. Khachatorov, V. Krakov, S. Lesin, and M. Tsirlin

Energetics Technologies Ltd.

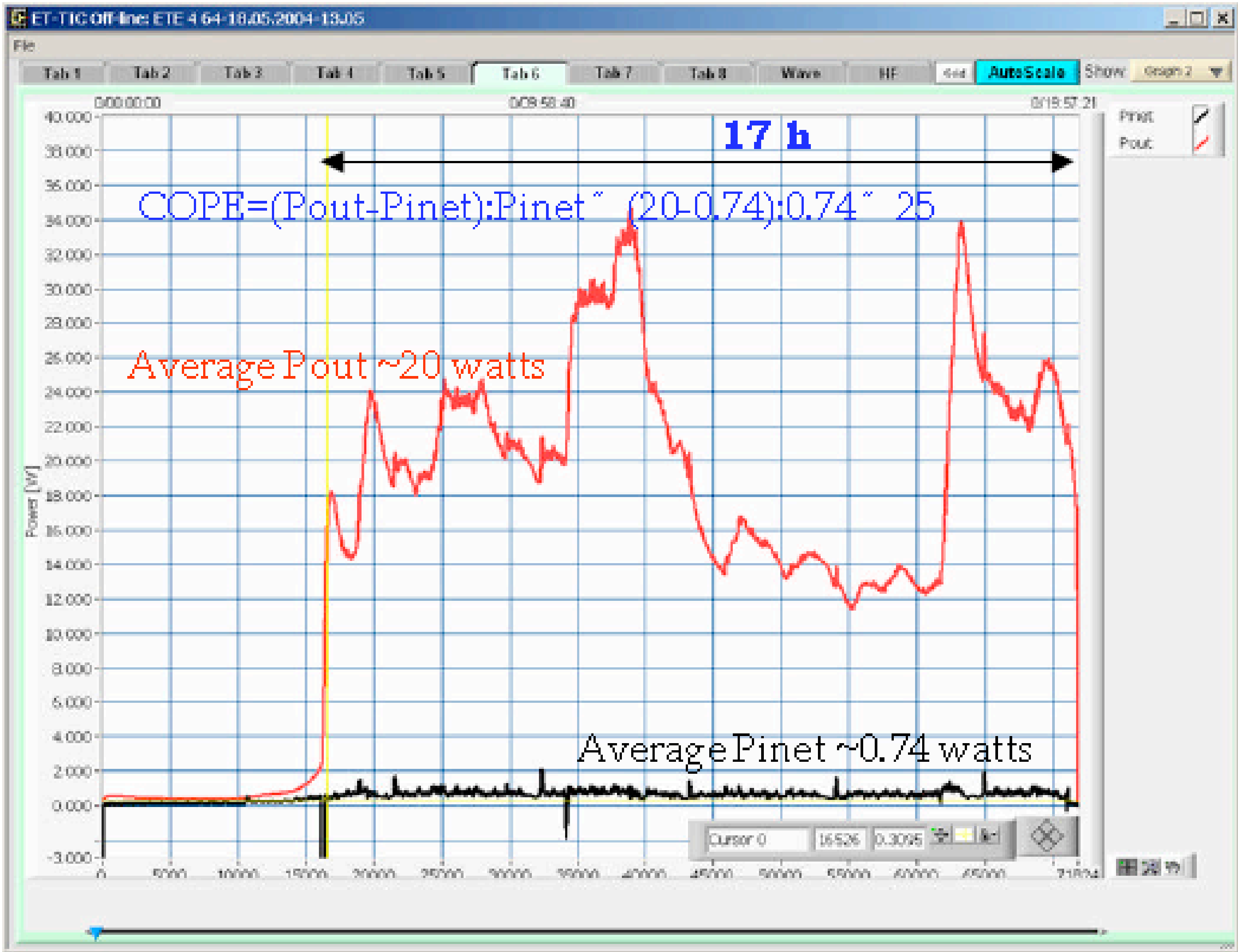
Omer, Israel
lesin@energetics.co.il

ICCF12 http://www.lenr-canr.org/acrobat/DardikIprogressin.pdf

Energetics Uses a Highly Non-Linear (Fractal) Input



Excess Power; Exp. # 64a



Excess Power of up to 34 watts; Average ~20 watts for 17 h

Transmutations

Iwamura and colleagues from Mitsubishi have evidence of a remarkable series of transmutations:

• At the level of one part per billion, atoms from films of either Cs or Sr have a nuclei that appear to acquire 4 protons and 4 neutrons, leading to the "reactions,"

$$^{133}_{55}Cs + 4d \rightarrow {}^{141}_{59}\mathrm{Pr}$$

and

$$^{88}_{38}Sr + 4d \rightarrow {}^{96}_{42}Mo$$

d=proton-neutron pair

Schematic Representation of Transmutation Experiment

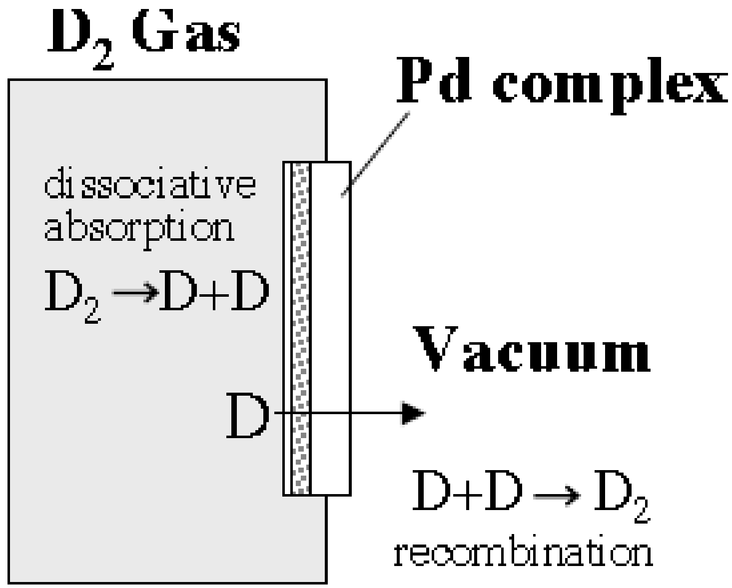
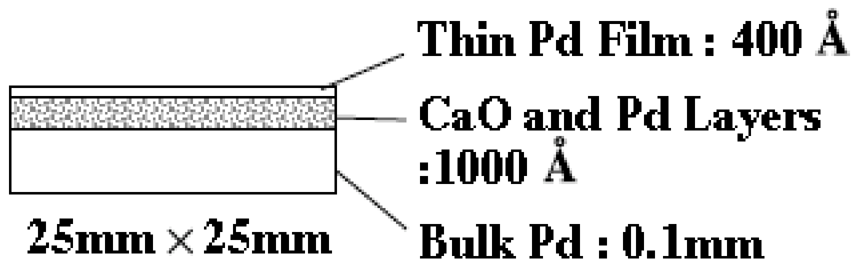


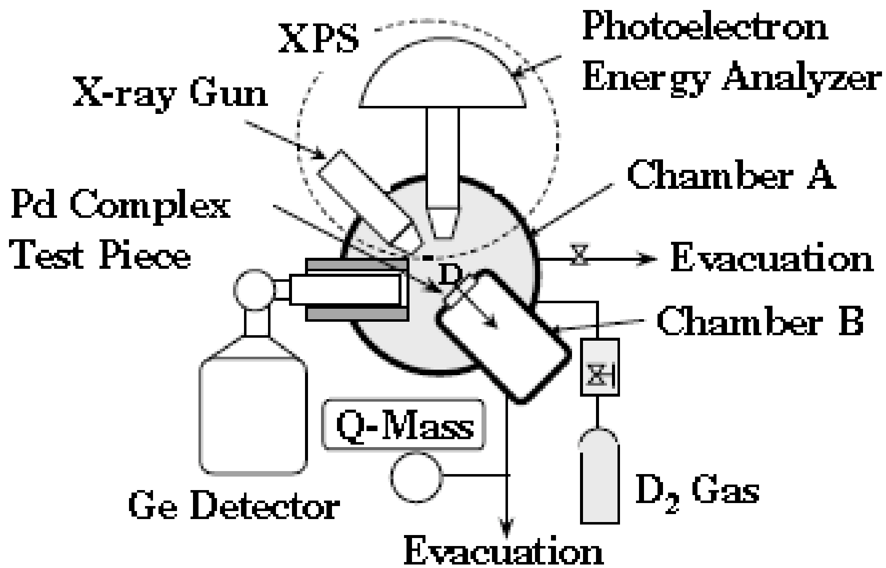
Fig. 1. D_2 gas permeation through the Pd complex.



Iwamura et al, Jpn. J. Appl. Phys. A, 2002. **41**: p. 4642.

http://www.lenr-canr.org/acrobat/IwamuraYelementalaa.pdf

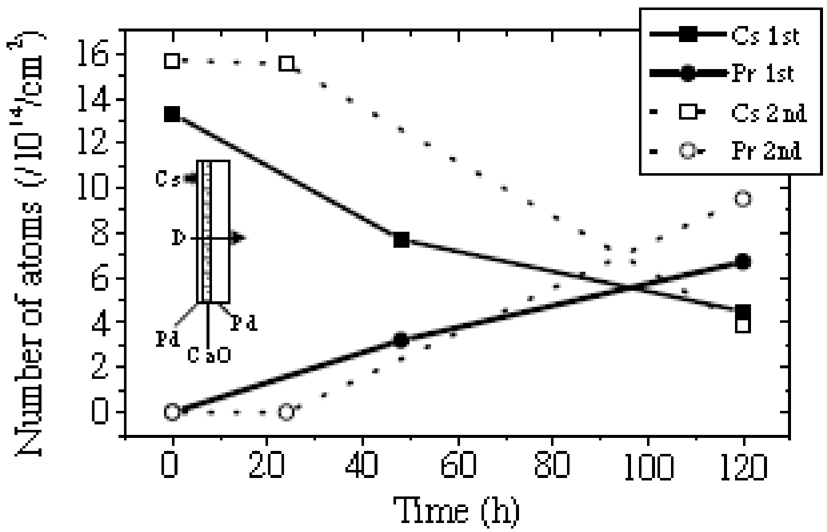
Experimental Set-up



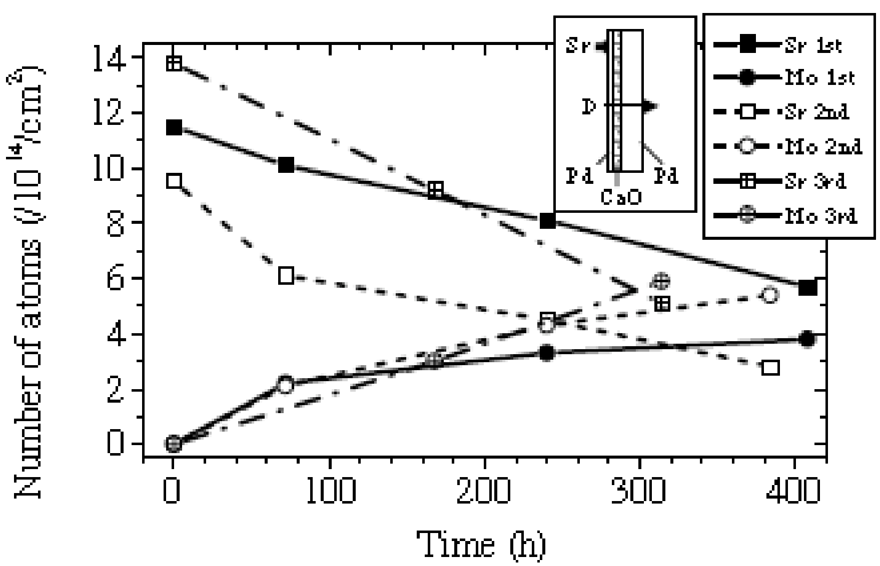
Iwamura et al, Jpn. J. Appl. Phys. A, 2002. **41**: p. 4642.

http://www.lenr-canr.org/acrobat/IwamuraYelementalaa.pdf

XPS Measurements Indicate Replacement of Cs(Sr) by Pr(Mo)



(a)



Other Transmutation Results

Table 2. Percentage deviation from natural isotopic abundance for select reaction products.

Isotopes	Mizuno et al. [8]	Miley et al.[a] [35]	Ohmori et al. [38]	Ohmori & Mizuno [39]	Chernov et al. [31]	Ohmori & Mizuno [40]	Ohmori et al. [41]
	1996	1997	1997	1998	1998	2000	2002
K-39							-21.33*
K-41							21.33*
Cu-63	30	3.6±1.6			44		
Cu-65	-30	-8.1±3.6			-44		
Fe-54	**		-0.81*	-0.8			
Fe-56	-21.75		-16.79*	-29.72			
Fe-57	18.88		16.58*	30.8			
Fe-58	**		1.01*	**			
Re-185	14.60					11.3	
Re-187	-14.60					-11.3	
Ag-107		3.9±1.2					
Ag-109		-4.3±1.3					
Ti-48					-33.30		
Ti-49					8.60		
Ti-50					17.80		
Cr-50						1.79	
Cr-52						-4.65	
Cr-53						2.85	
Ni-58						-4.98	
Ni-60						4.57	
Pb-206						13.5	
Pb-207						33	
Pb-208						-6.5	

* Averaged value from the reference paper; ** data not provided. [a]Performed by NAA such that error bars account for discrepancy in ± numbers (equal for two isotopes, sum to zero for multiple isotopes).

Miley and Shrestha, Proc. ICCF10. http://www.lenr-canr.org/acrobat/MileyGHreviewoftr.pdf

Why Low Energy Nuclear Reactions are not Publicized

- In 1996, I was asked to serve as guest editor of the Ethics in Science journal, *Accountability in Research*, in order to address questions associated with the potential breakdown of the scientific process in problems related to Cold Fusion

- Major problems in the process included: 1. Failures by editors and societies (the American Physical Society, in particular) to disseminate information about the topic objectively, 2. Scientific persecution, bias/lack of objectivity; and 3. Unscientific oversimplification

- Articles in a special 2 issue edition of Accountability in Research were published in 2000 and are available at http://www.lenr-canr.org/PPub0.htm#359:

Shamoo, A.E., *Editorial.* Accountability Res., 2000. **8**.

Chubb, S.R., *Introduction to the Special Issue of Accountability in Research Dealing With "Cold Fusion".* Accountability Res., 2000. **8**

Fleischmann, M., *Reflections on the Sociology of Science and Social Responsibility in Science, in Relationship to Cold Fusion.* Accountability Res., 2000. **8**.

Jones, S.E., *Chasing anomalous signals: the cold fusion question.* Accountability Res., 2000. **8**: p. 55.

Scaramuzzi, F., *Ten Years of Cold Fusion: An Eye-witness Account.* Accountability Res., 2000. **8**: p. 77.

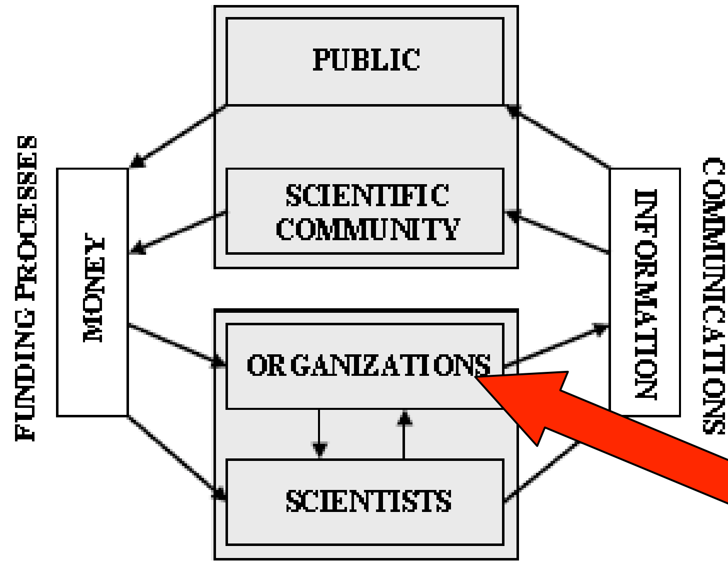
Goodstein, D., *Whatever Happened to Cold Fusion?* Accountability Res., 2000. **8**.

Bockris, J., *Accountability and academic freedom: The battle concerning research on cold fusion at Texas A&M University.* Accountability Res., 2000. **8**: p. 103.

Miley, G.H., *Some personal reflections on scientific ethics and the cold fusion 'episode'.* Accountability Res., 2000. **8**: p. 121.

Nagel, D.J., *Fusion Physics and Philosophy.* Accountability Res., 2000. **8**: p. 137.

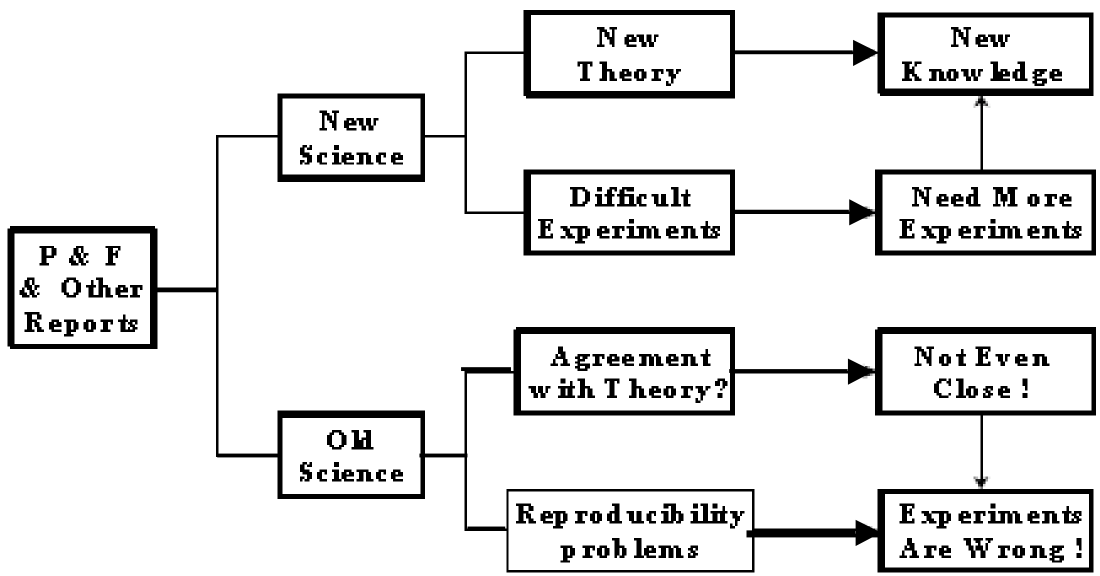
Why Low Energy Nuclear Reactions are not Publicized



D.J. Nagel

Major Error Made by American Physical Society on 1 May 1989 (D. Goodstein)

Schematic Representation of Acceptance or Denial of “Cold Fusion” as ”Normal Science”



D. J. Nagel

Coherent Deuteron Flux in Finite PdD Crystals:Implications for LENR

Scott R. Chubb

Infinite Energy Magazine

903 S. Frederick St., #6., Arlington, VA 22207

I Some Background about the “Coulomb Barrier” and quantum mechanics in understanding it

II Importance of Electromagnetism in $d + d \rightarrow {}^4He + \gamma$ and in the “actual reaction” *

III Background about Resonant Electromagnetic Interactions and how they can create non-local collisions

IV Implications associated with resonant/coherent effects and deuteron flux inside finite solids

V Other aspects associated with the underlying picture: trapped photons, potential resonant effects in non-linear systems

*Already Discussed

Resonant Electromagnetic-Dynamics
in "Real," Finite Solids
Explains the Fleischmann-Pons Effect

Four Views about the Coulomb Barrier in Cold Fusion

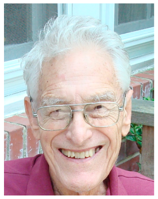
Nuclear Physicists Say: You can’t overcome it.

Robert L Park

Nuclear Physicists Say: You can’t overcome it. They seem to be wrong. But there is no accepted theory that can account for it.

David J Nagel

Nuclear Physicists don’t understand it. Solid State Physicists do. “Accepted theory” involving Nuclear Physics is wrong. Ground state quantum mechanics explains it.



Talbot A Chubb

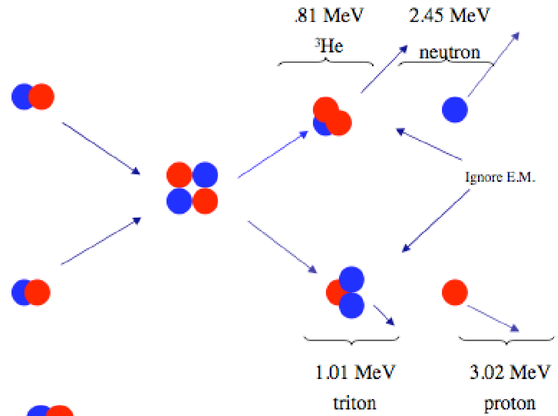
Time dependent quantum mechanics says it can be overcome using “conventionally accepted” theory and this will eventually “be accepted”.

Scott R Chubb

What is the Barrier?

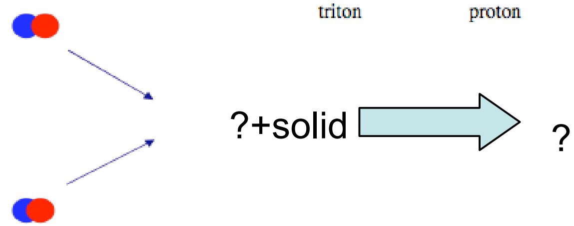
Robert L Park

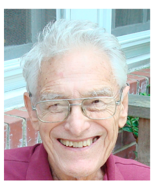
What we know



David J Nagel

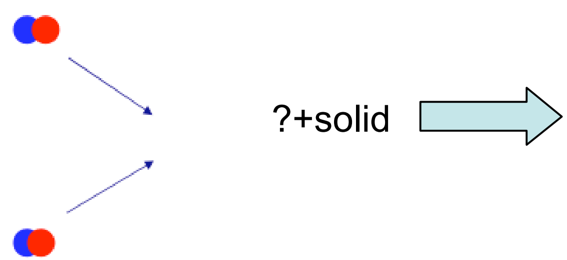
What we might also know





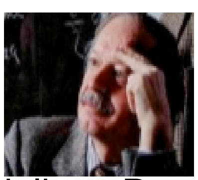
Talbot A Chubb

We know something new



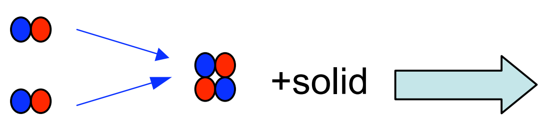
Quasi-particles, new forms of matter

Scott R Chubb



Giuliano Preparata

We know it:
Resonant Electrodynamics
(No Barrier)
Conventional Physics

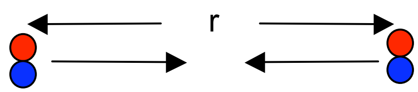


Waves, known time dependent processes, with real equations

How Preconceptions have Confused Us about “The Barrier”

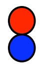
What is “The Barrier?”

Classical:



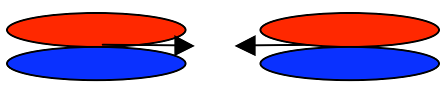
Force $\propto \frac{e^2}{r^2} \xrightarrow{r \to 0} \infty$

Infinite Forces at r=0 create barrier

Deuteron  Charge: +e

- This is a point-particle picture.
- Point particles cannot collide when infinite forces occur.
- This creates a “Conceptual Barrier.”
- But it is not the “Barrier”

Semi-Classical:



Energy $\propto \frac{e^2}{r} \xrightarrow{r \to 0} \infty$

Infinite Energy but “barrier” is different

It involves Quantum Mechanics and Energy

- “Particles” are not point-particles. They are waves that can overlap.
- This is the real situation in conventional fusion. The barrier is the “Coulomb Barrier”.
- But Equations are approximate
- This has created a “Conceptual Barrier.”

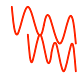
The Real Barrier: “Understanding” Quantum Mechanics

Julian Schwinger 1918-1994

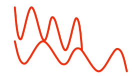
ICCF1

Virtual Process

Initial State Waves



Final State Waves



Collision

Change in Energy

$$\langle Initial | \; \mathbf{V} \; | Final \rangle$$

Forward in Time $\longrightarrow$

The Real Barrier: “Understanding” Quantum Mechanics

Julian Schwinger 1918-1994

ICCF1

Virtual Process

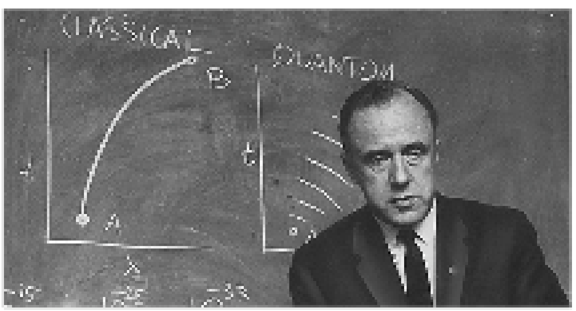
Initial State Waves	Collision Change in Energy	**Final State Waves**	**Final State Waves**	Collision Change in Energy	**Initial State Waves**
$\langle Initial|$	**V**	$|Final\rangle$	$\langle Final|$	**V**	$|Initial\rangle$

Forward in Time → ← Backward in Time

Virtual Power = $\frac{2\pi}{\hbar}\langle Initial|\mathbf{V}|Final\rangle \times \langle Final|\mathbf{V}|Initial\rangle$

Reversible: Forward Power=Backward Power, Power can be arbitrarily large or small

Rate = Weighted Sum of Virtual Power changes that conserve energy



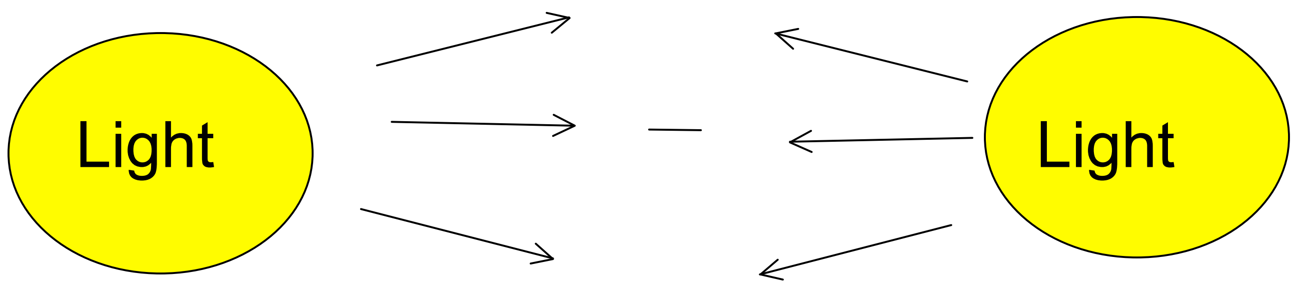
John Archibald Wheeler (1911 - 2008)

In Virtual Processes:

1. Future events can affect past events.
2. Particles that are far apart can interfere with each other.
3. Sum over final states means creative physics is possible

How Future can Affect Past in Quantum Mechanics

- Photons and Light are reversible in time, Feynman-Wheeler:



= Radiation

Forward in Time

Backward in Time

- There is no preferential direction in time because of this

- Collisions (losses of information) create “time”

Scott R Chubb

• “Understanding” Quantum Mechanics involves recognizing this. For this reason Quantum Mechanics is a language, “not reality”, “reality” requires collisions.

•Emphasis in Cold Fusion has involved wrong assumptions about collisions and confusion about Quantum Mechanics.

• **In Solids, collisions are electromagnetic, NOT NUCLEAR**.

Talbot Chubb and I suggested in 1989:

Deuterons, in fully-loaded palladium deuteride, could behave very differently than in free space, by occupying energy band states.

Based on this conjecture, we suggested :

The normal rules about fusion might be wrong

Confusion has occurred (David Lindley, Nature 344, 375, 1990)

We Suggested Two important reasons for this:

Misconceptions, about the experiments,

and

Limitations of conventional energy band theory.

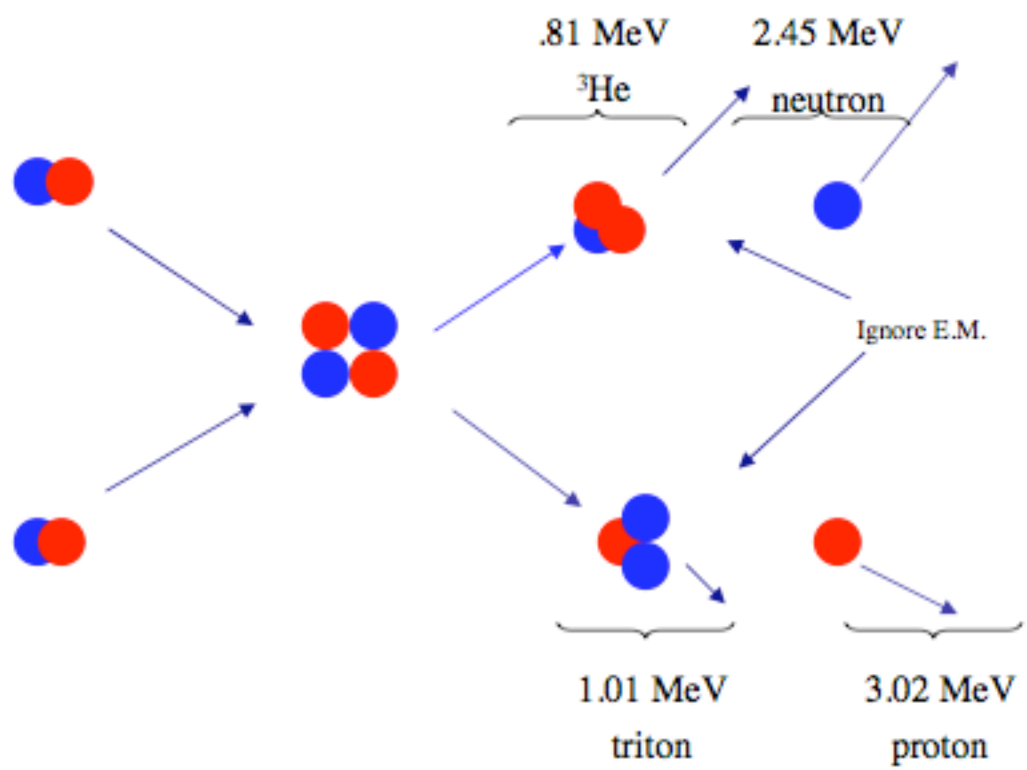
Importance of Electromagnetism in the Process and misconceptions about this

- In conventional nuclear fusion, a static electromagnetic interaction applies because the reacting particles have high velocity
- This is relevant in these kinds of situations but certainly does not have to be relevant in a solid because in a solid, time-dependent changes involving many particles can become relevant.
- Although the initial band theory idea that Talbot Chubb and I proposed seemed to be preposterous at the time, by responding to the critics, new ideas evolved from our thinking.
- A key point in what we developed is associated with the potential relevance of finite size and finite time-scales, as it might apply in band theory.
- A natural generalization of band theory, in fact, does exist, which is associated with the underlying formalism that Felix Bloch used, in his formulation of transport phenomena, which involves multiple-scattering theory, as opposed to the conventional “picture” that has been used to introduce ideas related to band theory.
- When this alternative picture is used, finite size effects can be introduced in a manner that can explain how many-body effects, associated with a finite solid can explain how a form of $d + d \rightarrow {}^4He + \gamma$ reaction can occur in which the gamma ray can be suppressed

Summary of Key Reasons why Electromagnetism is Important

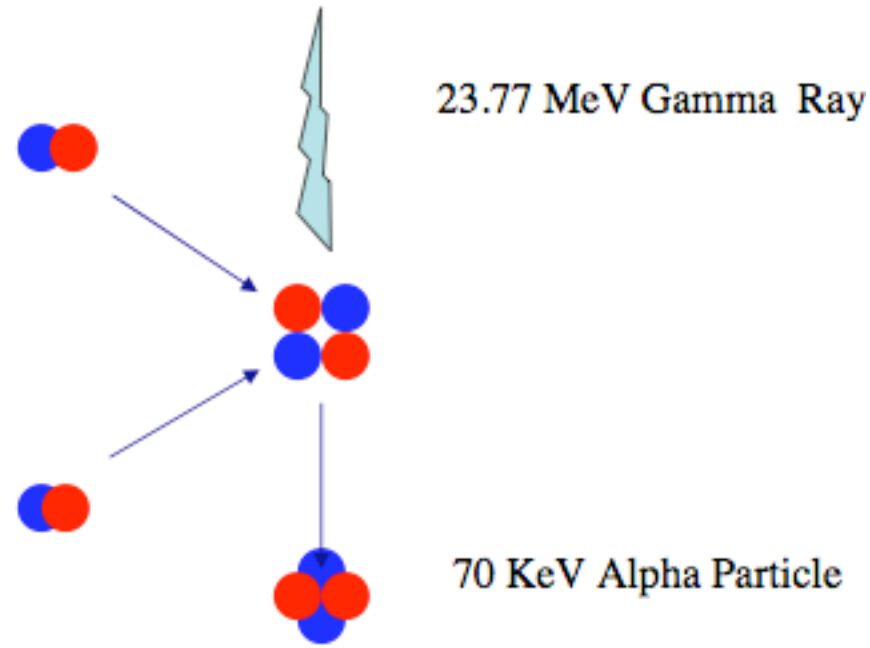
- "Coulomb barrier" requires "static" Electromagnetic Interaction (EMI)
- In $d+d \rightarrow {}^4He+\gamma$, EMI is not static; "Coulomb barrier" replaced by QED
- QED couples to all length scales
- Superficially, QED " not treated rigorously in Condensed Matter Physics." But, in fact, given appropriately interpreted pictures, this is not true.
- Missing ingredient in how Condensed Matter Physics (CMP) relates to CMNS:
  -Understanding "overlap" can occur without high energy particles.
- This happens all the time in CMP. How this happens not treated rigorously.
- Rigorous Statement Involves Many Particles and the fact that:
  -Many particles can act like a single particle/wave by moving precisely the same way;
  -Momentum can change abruptly, locally, without any particle acquiring high velocity

Facts About Conventional Fusion



EMI can be ignored. Static, Coulomb Barrier applies.

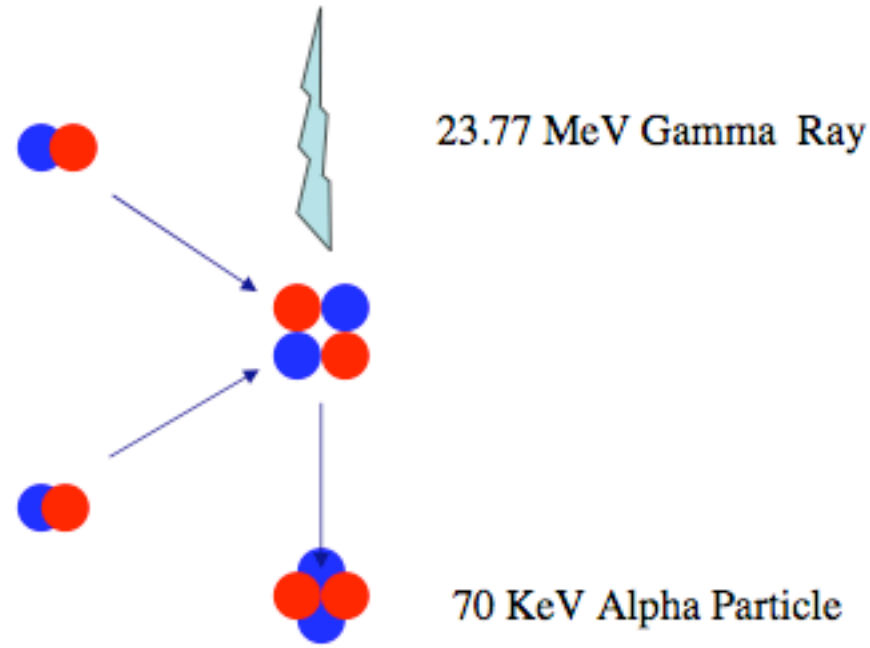
Key Limitation of "Conventional" Nuclear Fusion Theory



- "Secret, 'Rare' Reaction": $d+d \rightarrow {}^4He+\gamma$
- Common assumption: energy release too large
- Assumption is not right. Reaction is Rare because:

  * Reaction involves EMI

Additional Facts About Additional Reaction



- Rate of "Secret Reaction" is 10^7 smaller than other reactions
- Not cited in conventional fusion literature for this reason
- $d+d \longrightarrow {}^4He + \gamma$ is rare, but reverse reaction ${}^4He + \gamma \longrightarrow d+d$ is well-known
- ${}^4He + \gamma \longrightarrow d+d$ teaches us that: In $d+d \longrightarrow {}^4He + \gamma$,
  - ❖ Simplified Coulomb Barrier tunnelling does not apply.
  - ❖ Far from reaction, EMI required: d+d must be prepared appropriately

Historical Note about Importance of EMI in LENR

- Preparata and Schwinger did not know about

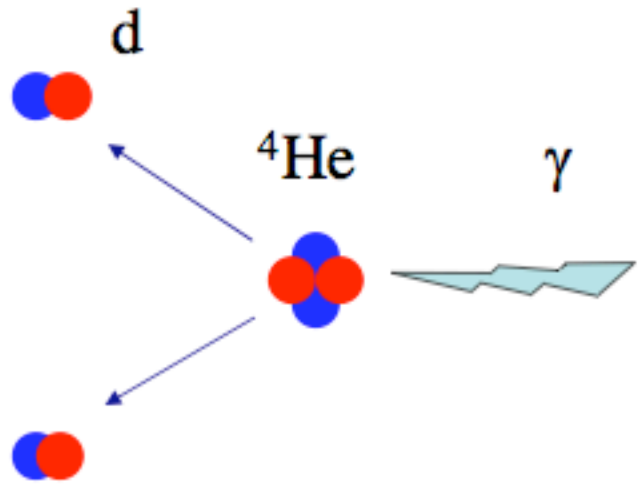
$$^{4}\mathrm{He} + \gamma \rightarrow \mathrm{d+d}$$

- Both believed EMI was important, either implicitly (in the case of Schwinger) or explicitly (in the case of Preparata)

Wrong Intuitive Picture has resulted from not Including EMI in $d+d \rightarrow {}^4He+\gamma$

- Because all d-d fusion reactions conserve isospin, it has been widely assumed that the dynamics is driven by the strong force interaction (SFI), NOT electromagnetic interaction (EMI)
- Major source of confusion is the assumption that the strong force dictates both the dynamics and the available energy states and transitions
- True for the conventional reactions but not for $d+d \rightarrow {}^4He+\gamma$
- Thus, most nuclear physicists assume: 1. EMI is static; 2. Dominant reactions have smallest changes in incident kinetic energy (T); and (because of 2), $d+d \rightarrow {}^4He+\gamma$ suppressed.

Further Implications of $^4He + \gamma \rightarrow d+d$



- Coulomb Barrier does not apply-- more general QED Barrier required

    * Strong Force determines energy levels, not dynamics

    * Far from location of reaction, d+d has spin=0, angular momentum = $2\hbar$

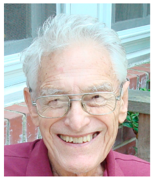
- Time Reversal invariance$\rightarrow$ Also true for $d+d \rightarrow {}^4He$

- QED effects can become important: mv=p-e/cA $(mv \neq p)$

Pictures vs Equations and History of Chubb and Chubb Theory

Key Initial Chubb and Chubb Assumption, a Picture: Deuterons (D's) in solids are different:

1989-1997



Talbot A Chubb

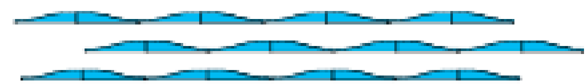
D+D->helium-4 without γ-ray, based on Ion Band State idea, proposed by S Chubb

Scott R Chubb

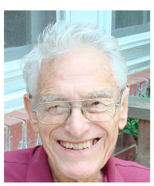
D's in 1 or more waves, at many places, at once; later, helium-4 with high energy replaced by helium-4 wave, based on T Chubb idea: D+D->helium-4 without γ-ray

Picture: Ion Band States

D_2 or $D^+ \rightarrow D^+$ in Ion Band States



Later: 1997-present



Talbot A Chubb

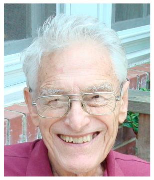
Scott R Chubb

Time independent single quasi-particle stationary state quantum mechanics, involving Ion Band States, with proposed pictures relating to PdD and systems other than PdD, including Flake-like 2-dimensional Ion Band States in Iwamura experiments, and the same states in Oriani experiments

Time Dependent Quantum Mechanics, Equations based on known physics, including resonant electro-dynamics (implicit in earlier theory) in D+D$\rightarrow$?+new physics including pictures proposed by T. Chubb, but with "real equations" that include details about collisions

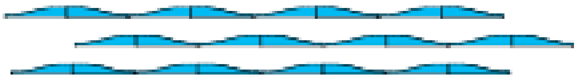
Initial Pictures for Overcoming "The Barrier" Quantum Mechanically

Time Independent Quantum Mechanical Picture with Static Coulomb Potential V



Talbot A Chubb

D_2 or $D^+ \rightarrow D^+$ in Ion Band States in fully loaded $PdD_{1\pm\delta}$ takes place



Scott R Chubb

Nuclear reactions occur with helium-4 created outside PdD

Time Independent Picture involving "stationary" forms of matter involving D+ occupying ion band states that are able to have appreciable overlap with each other as a result of interactions with each other and the outside environment. From this new idea, time dependent forms of interaction are introduced based on approximate ideas about how nuclear reactions might occur. Associated language involves conventional solid state physics with a slightly modified way of expressing it in which hydrogen nuclei might behave in the same way that electrons behave in a near-equilbrium environment. Underlying principles are consistent with conventional charge transport involving electrons in solids. Potential sources of error are associated with potentially poorly understood ways that particle-particle interactions can occur similar to comparable areas of error in quasi-particle interactions in solids.

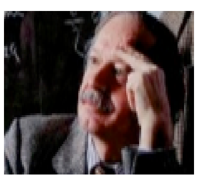
Time Dependent Quantum Mechanical Picture with Time-Varying Electromagnetic Potential V

$$\text{Virtual Power} = \frac{2\pi}{\hbar}\langle Initial|\mathrm{V}|Final\rangle \times \langle Final|\mathrm{V}|Initial\rangle$$

Scott R Chubb

Reversible: Forward Power = Backward Power, Power can be arbitrarily large or small

Rate = Weighted Sum of Virtual Power changes that conserve energy



Giuliano Preparata

How communication takes place involves us. This is basic. This is Quantum Mechanics

Overcoming the Real Barrier: "Understanding Collisions" in the Fleischmann-Pons Effect

Julian Schwinger 1918-1994
ICCF1

Virtual Process

Initial State Waves	Collision Change in Energy	**Final State Waves**	**Final State Waves**	Collision Change in Energy	**Initial State Waves**
$\langle Initial\vert$	$\mathbf{V}$	$\vert Final\rangle$	$\langle Final\vert$	$\mathbf{V}$	$\vert Initial\rangle$

Forward in Time ⟶ ⟵ Backward in Time

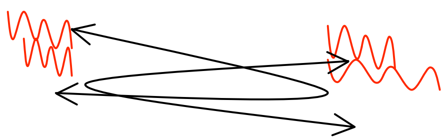
$$\text{Virtual Power} = \frac{2\pi}{\hbar}\langle Initial|\mathbf{V}|Final\rangle \times \langle Final|\mathbf{V}|Initial\rangle$$

"Virtual Collision"

Rate that Waves come together (overlap) defines "virtual collision" Matrix Element $\langle Initial|\mathbf{V}|Final\rangle$:

Scott R Chubb

Initial State Waves **Final State Waves**



$$= \langle Initial|\mathbf{V}|Final\rangle = i\hbar \times \text{(Rate that overlap between waves changes)}$$

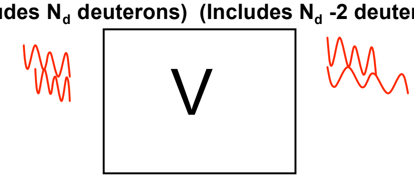
Involves changes in particle flux j at boundaries of collision and density ρ

$$= i\hbar\left(\int d^3r\, \frac{\partial\langle Initial|\rho(r)|Final\rangle}{\partial t} + \int_{\text{Boundary of V}} dA\, \hat{n}\bullet\langle Initial|\vec{j}(r)|Final\rangle\right)$$

0

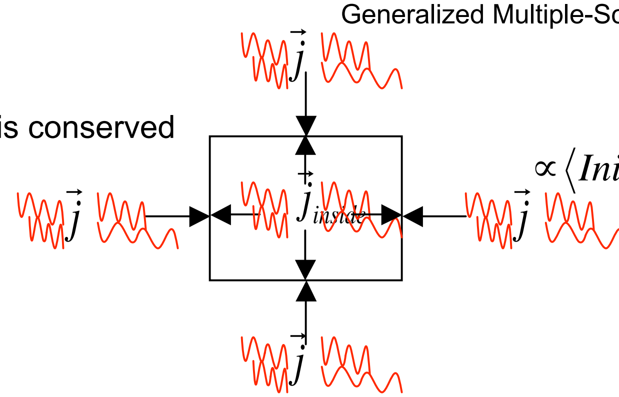
When energy is conserved

Initial State Waves **Final State Waves**
(Includes N_d deuterons) **(Includes N_d -2 deuterons)**



Can include all (~10^{23}) Particles in Solid.
(Required by Quantum Mechanics)

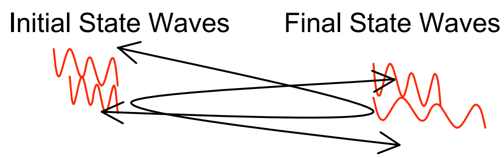
Generalized Multiple-Scattering



$\propto \langle Initial|\mathbf{V}|Final\rangle$

Claim: This logic applies in the Collisions in the Fleischmann-Pons Effect

Role of Overlap Rate Magnitude and Extent in Electrodynamics of Nuclear Reactions



= $i\hbar\,\times$(Rate that overlap between waves changes)

Scott R Chubb

High Rate in Small Region--Conventional Nuclear Physics--not interesting!

High Rate but over large region-- Possibly LENR--possibly interesting

Low Rate but over small or large region-- Possibly LENR--very interesting

Near Resonance Condition: Nearly vanishing rate over some region--extremely interesting!

Occurs when energy-conserving single rate of overlap or sum of rates becomes small inside V

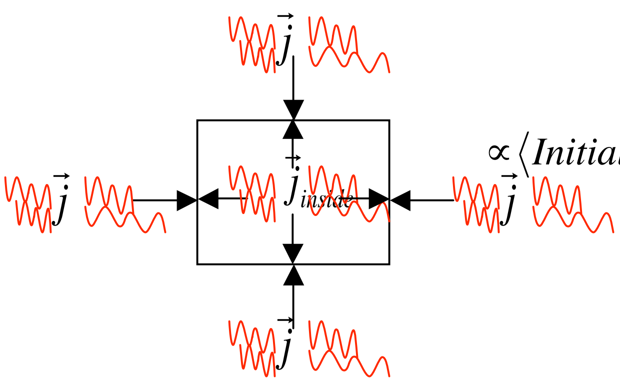
"Resonant Collisions" occur when energy is conserved and total flux of overlap inside Collision Region vanishes:

$$\int d^3r\, \frac{\partial\langle Initial|\rho(r)|Final\rangle}{\partial t} + \int_{\substack{\text{Inside Boundary}\\ \text{of V}}} dA\;\; \hat{n}\bullet\langle Initial|\vec{j}(r)|Final\rangle = 0$$

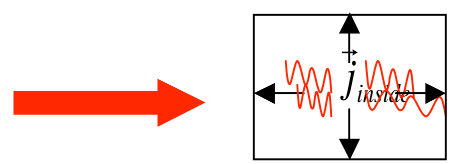
$\downarrow$

0

When energy is conserved

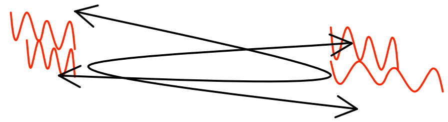


$\propto\langle Initial|\mathbf{V}|Final\rangle$ Resonant Condition



=0

Role of Overlap Rate Magnitude and Extent in Electrodynamics of Nuclear Reactions



$= i\hbar \times$(Rate that overlap between waves changes)

Scott R Chubb

High Rate in Small Region--Conventional Nuclear Physics--not interesting!

High Rate but over large region-- Possibly LENR--possibly interesting

Low Rate but over small or large region-- Possibly LENR--very interesting

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Occurs when energy-conserving single rate of overlap or sum of rates becomes small inside V

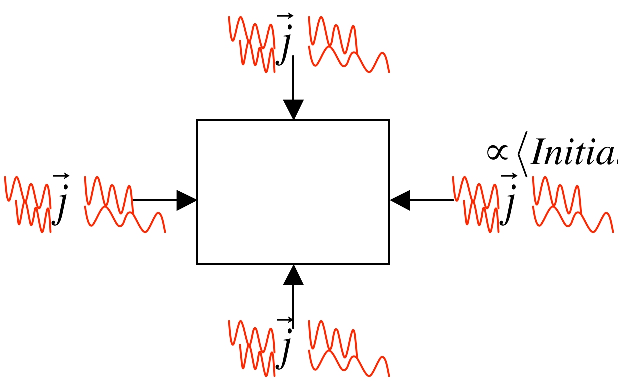
"Resonant Collisions" occur when energy is conserved and total flux of overlap inside Collision Region vanishes:

$$\int d^3r \, \frac{\partial \langle Initial|\rho(r)|Final\rangle}{\partial t} + \underset{\substack{\text{Outside Boundary} \\ \text{of V}}}{\int dA} \; \hat{n} \bullet \langle Initial|\vec{j}(r)|Final\rangle = \frac{1}{i\hbar}\langle Initial|V|Final\rangle$$

$\downarrow$

0

When energy is conserved



$\propto \langle Initial|\mathbf{V}|Final\rangle$ Resonant Condition → Collisions:

- Become non-local
- Can involve many waves
- Can involve coherence

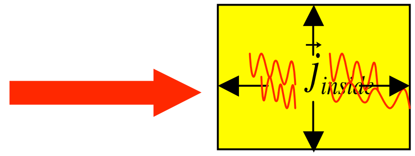
Nearly Resonant Collisions →

- Can increase in magnitude with time

Claim: Fleischmann-Pons Effect Involves "Weak", Nearly Resonant Collisions

Resonant Electromagnetic Dynamics in the Fleischmann-Pons Effect

Resonant Condition



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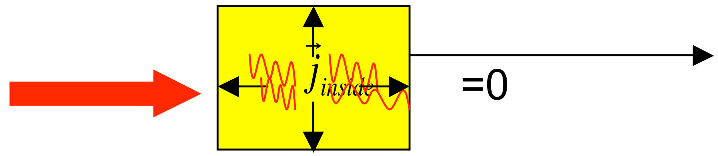
Collision Region Does Not Move

Near Resonant Condition



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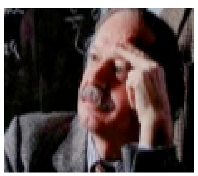
Collision Region (Solid) Moves Rigidly



Giuliano Preparata

All currents/photons in a solid can be absorbed (“trapped”) before they are released

Coulomb Barrier replaced by time-dependent non-linear, coherent photon absorption

Scott R Chubb

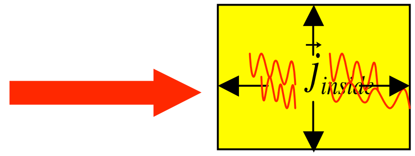
This is implicit in conventional solid state physics but not rigorously treated.
Trapped photon picture occurs when photons resonantly couple to the solid

New Ideas, common to both theories:

- Resonant electromagnetic dynamics can make deuteron collisions--“wave-like”
- Treatment of changes at boundaries/surfaces of solids is key
- Solid can move coherently, in nearly rigid manner

Resonant Electromagnetic Dynamics in the Fleischmann-Pons Effect

Resonant Condition



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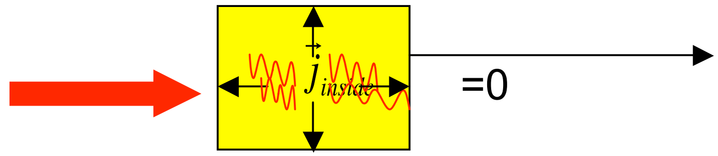

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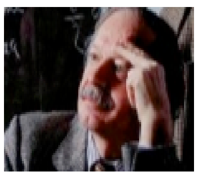
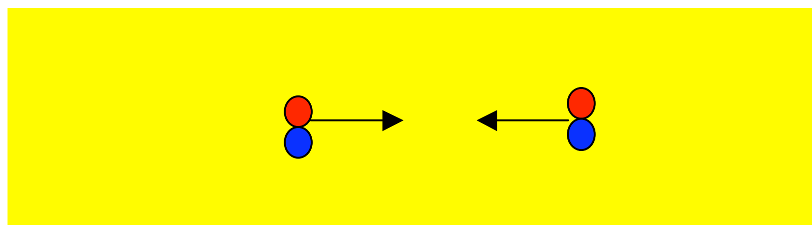


Giuliano Preparata

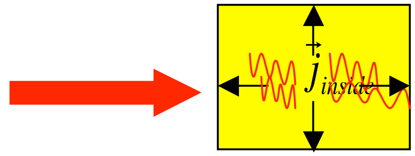


Initially deuterons are “particles” inside solid

Scott R Chubb

Resonant Electromagnetic Dynamics in the Fleischmann-Pons Effect

Resonant Condition



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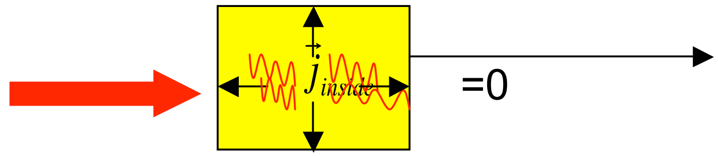

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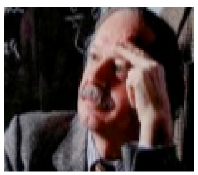

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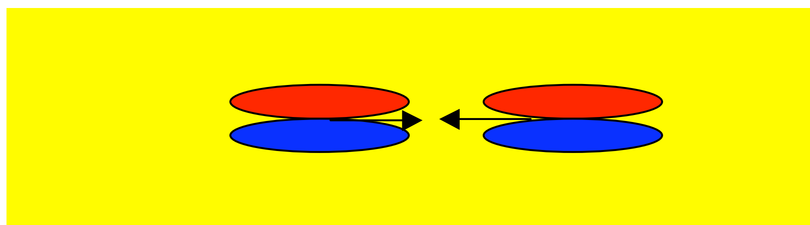
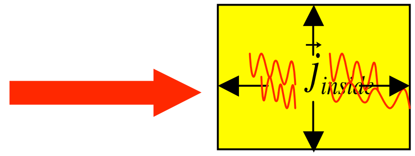


Deuterons become “waves” by coupling to rigid motion during “Near Resonance”
Motion picked to involve oscillation of solid with “reasonable frequency”

Scott R Chubb

Resonant Electromagnetic Dynamics in the Fleischmann-Pons Effect

Resonant Condition



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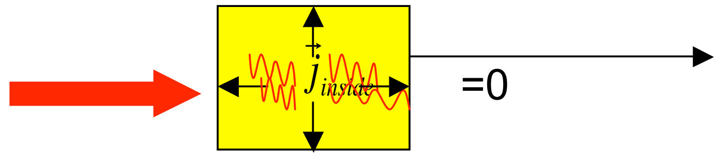

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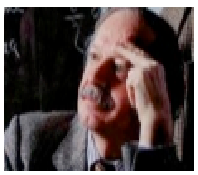

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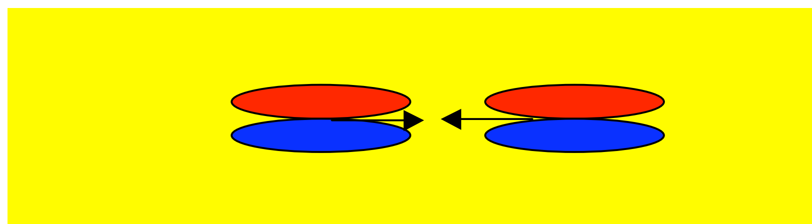


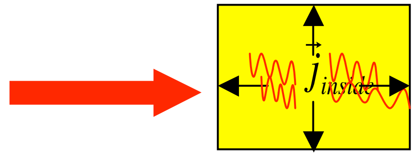
Deuterons become "waves" by coupling to rigid motion during "Near Resonance"
Motion picked to involve oscillation with "reasonable frequency"

Scott R Chubb

Initially N_d deuterium atoms approach fully-loaded PdD.

Resonant Electromagnetic Dynamics in the Fleischmann-Pons Effect

Resonant Condition



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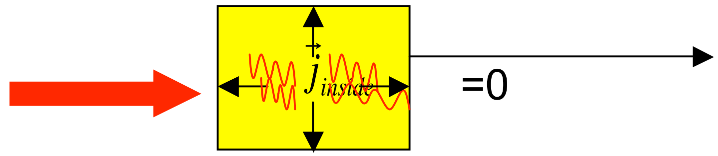

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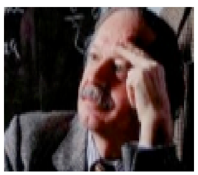

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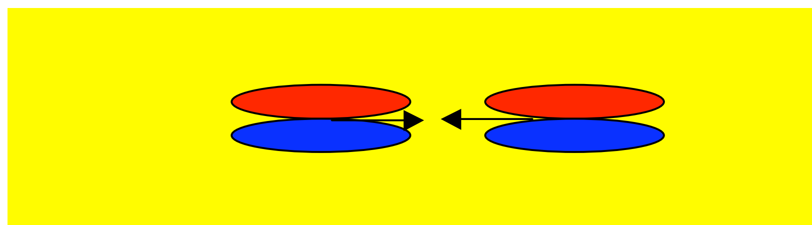

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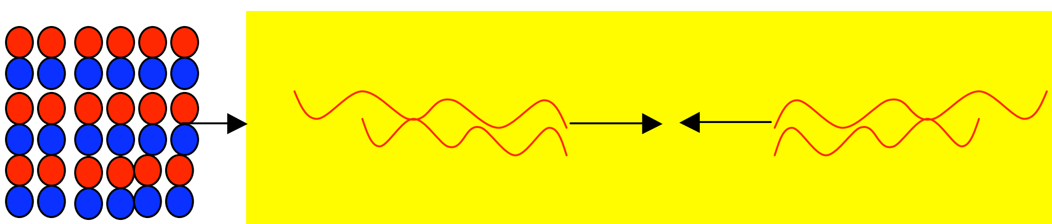
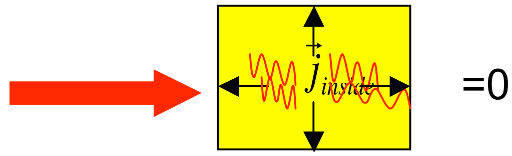


N_d deuterium atoms couple to fully-loaded PdD. A fraction of them become deuteron waves through “Near Resonance” coupling and resonantly collide.

Resonant Electromagnetic Dynamics in the Fleischmann-Pons Effect

Resonant Condition



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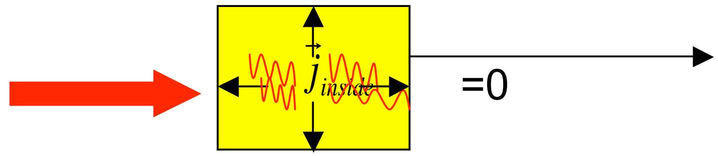

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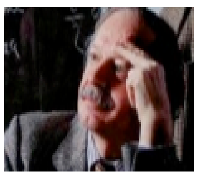

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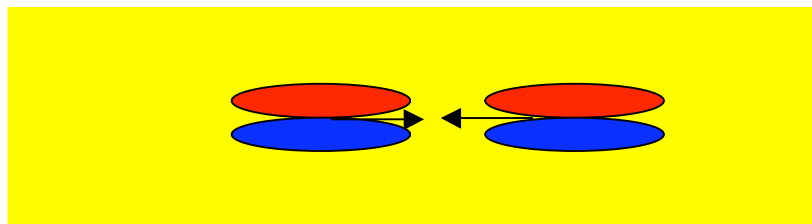

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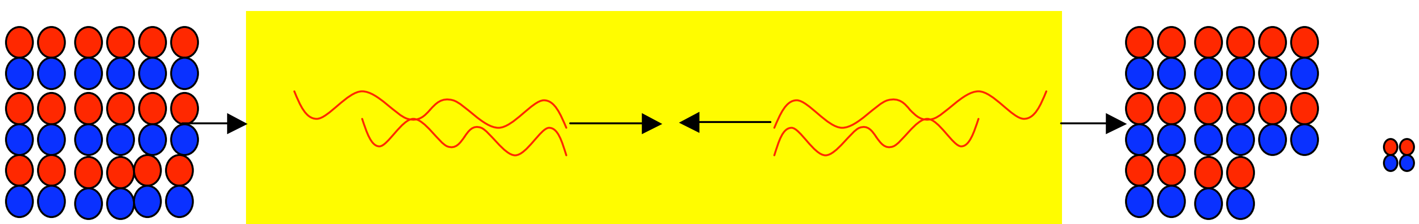
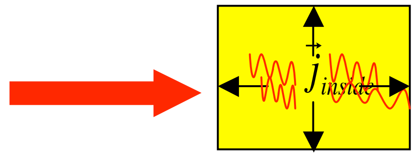


Through “Near Resonance” coupling, ^{4}He is created. In final state, N_d initial state deuterium atoms become N_d -2 deuterium atoms and one helium-4 atom

Resonant Electromagnetic Dynamics in the Fleischmann-Pons Effect

Resonant Condition



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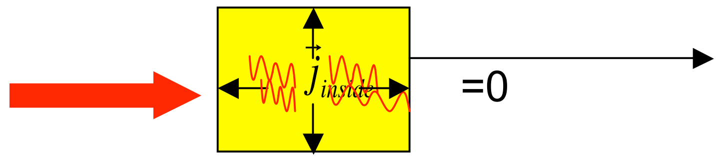

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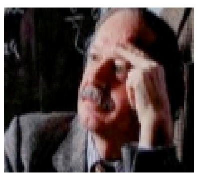

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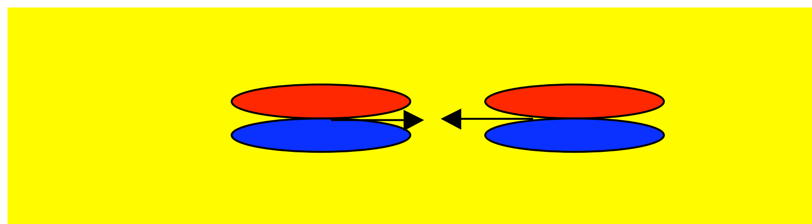

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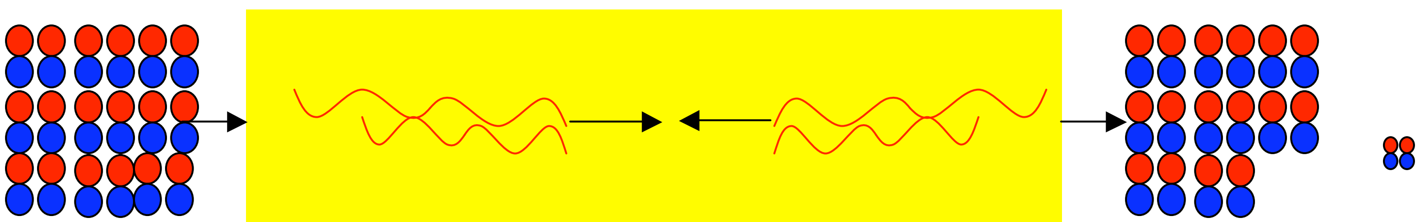


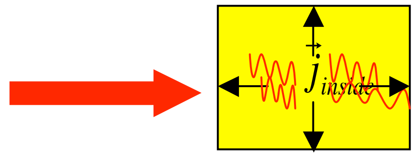
Important forms of coherence, result because solid can move rigidly: E(p)=E(p+ $\frac{h}{\lambda_D(t)}$)

$$\lambda_D(t) \equiv \lambda_{DeBroglie} = \frac{a}{n} = \frac{h}{p(t)}$$

p(t)=force x t , grows with n

Resonant Electromagnetic Dynamics in the Fleischmann-Pons Effect

Resonant Condition



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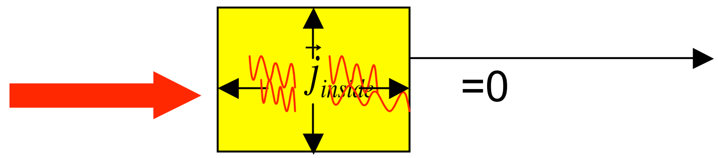

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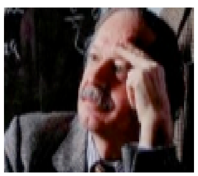

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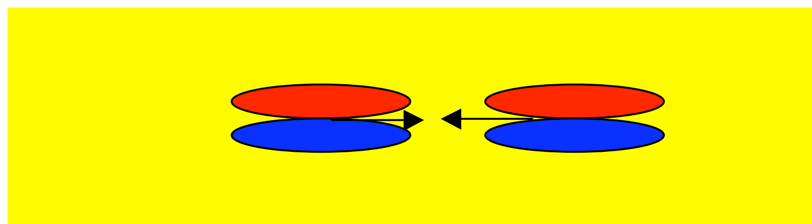

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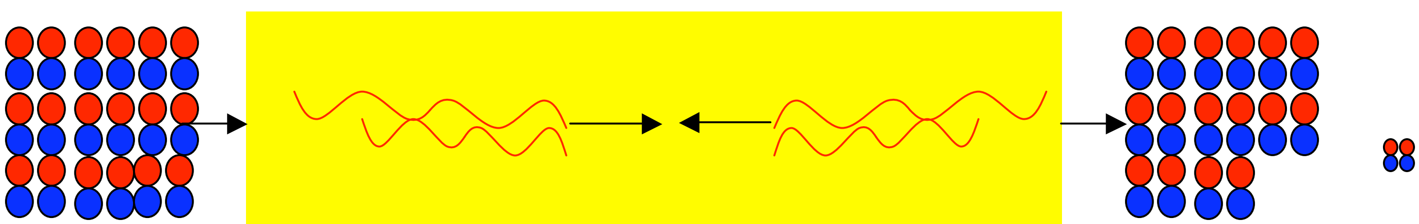

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$p(t_n)$=force x t_n, grows with n

EMI Resonant Interactions in Finite Solids

- Scattering Theory for Photons (Bragg Scattering):

$$w \equiv w(k) = c \times k = w(k+g) = c \times |k+g|$$

–Boundary Conditions Satisfied at Boundaries of Solid

- Multiple Scattering Theory for Charged Particles:

$$\varepsilon \equiv \varepsilon(k) = \varepsilon(k+g)$$

- Wave vectors (k) and reciprocal lattice vectors g minimize outside coupling

- Flux of each kind of particle is conserved

- Ground State and Lowest Lying Excited States couple only through rigid translations that do not alter separations between particles

- Then, semi-classical theory of transport applies

Important Finite Effect

$$Force(e\vec{E}) \times time(t) = e\vec{E}t = Boundary \quad Energy$$

Time t, is discrete

Each time t x force conserves boundary energy resonance occurs

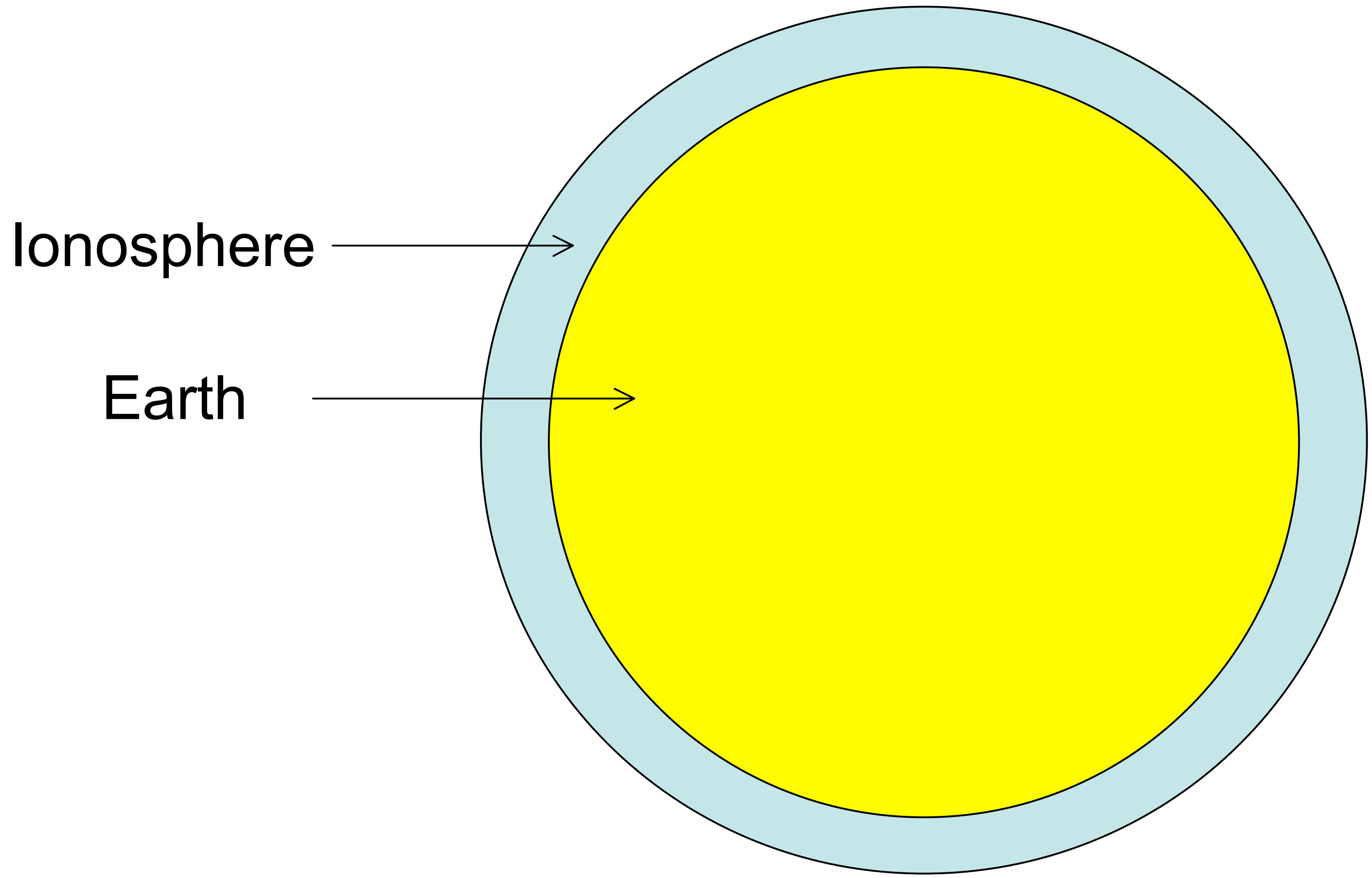
Resonant coupling, like this, can explain how momentum can build up

Effect can explain how reactions can occur without high energy particles

Effect can be quantified and can be used to predict how to create reactions

NMR-like coupling (work in progress with Letts) as well as Laser-induced coupling in work involving Letts and Hagelstein is consistent with this.

Other aspects associated with the underlying picture:
Trapped Photons in our Atmosphere



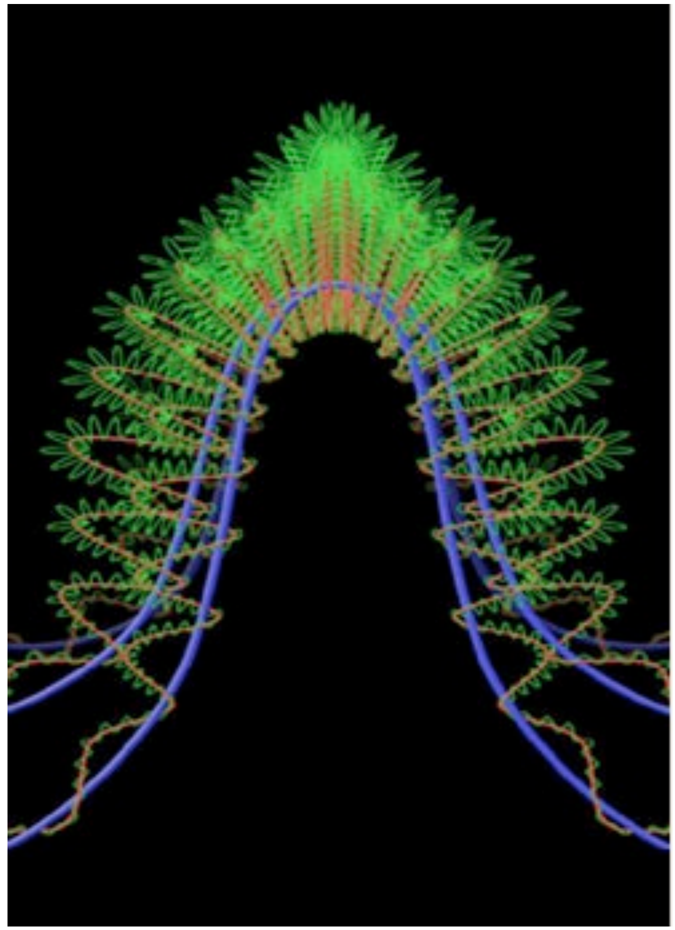
AM Radio Transmissions are "trapped"

Higher Frequency Transmissions Escape

Coherent Oscillations, envisioned by Preparata mimic this

Lightning and other long-wave electromagnetic effects involve this

Other aspects associated with the underlying picture:
resonant effects in non-linear systems



Super-wave, courtesy Irving Dardik

Summary

I have given background about:

- The “Coulomb Barrier” and quantum mechanics in understanding it
- Importance of Electromagnetism in the “relevant reaction,” involving $$d + d \rightarrow^4 He + \gamma$$
- Resonant Electromagnetic Interactions and how they can create the kinds of non-local collisions that are relevant in Condensed Matter Nuclear Science fusion
- Implications associated with the underlying picture
- A potentially important suggestion involving changes in applied and measured responses to electromagnetic fields