Lattice Energy LLC

Toyota confirmed Mitsubishi's LENR transmutation results

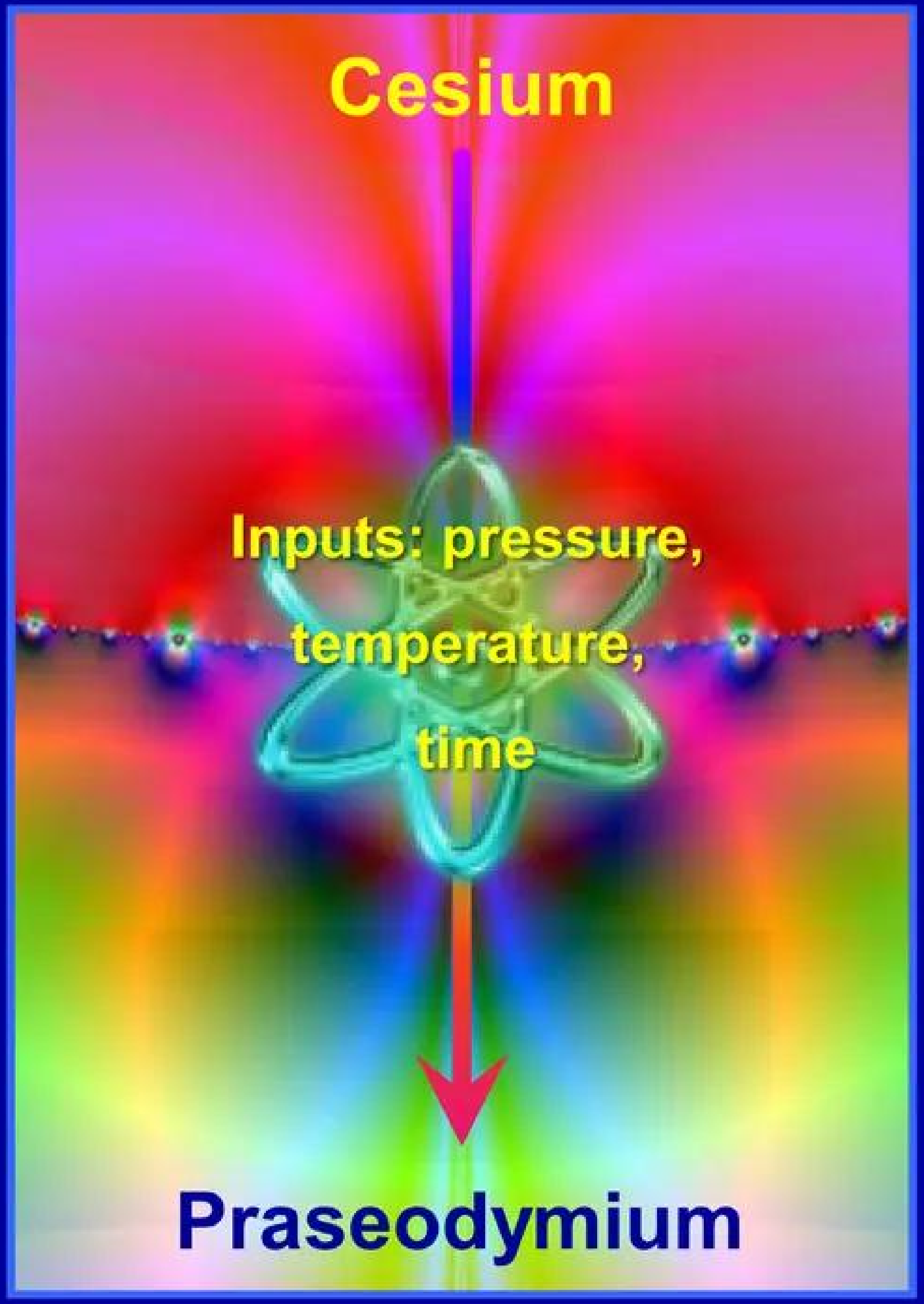
Successfully transmuted stable Cesium into stable Praseodymium

Used previous experimental method of Mitsubishi Heavy Industries

Only modest temperatures/pressures/time required to produce results

Widom-Larsen theory of LENRs explains all of this experimental data

LENR transmutation



Lewis Larsen

President and CEO
Lattice Energy LLC
October 31, 2013

"For the truth of the conclusions of physical science, observation is the supreme Court of Appeal."
Sir Arthur Eddington (1939)

Contact: 1-312-861-0115
lewisglarsen@gmail.com
http://www.slideshare.net/lewisglarsen/presentations

LENR transmutation

Lattice Energy LLC

Welcome to the New World of the future of energy

Clean green low energy nuclear reactions (LENRs) offer great potential

From older problematic energy sources | **To a greener less expensive tomorrow**

Evolution of nuclear technology

Fossil fuels + fission + fusion → LENRs + renewables

Contents

Lattice Energy LLC

Key take-aways

Cesium (Cs)

↓

Praseodymium (Pr)

Transmutations produced under mild conditions

Key take-aways

- ✓ In Oct. 2013, Toyota published a paper in the peer-reviewed *Japanese Journal of Applied Physics* which confirmed important experimental results that Mitsubishi Heavy Industries had published back in 2002. MHI had claimed transmutation of Cesium into Praseodymium via the forced diffusion of Deuterium gas through a thin-film heterostructure containing elemental Palladium using a permeation method pioneered by Mitsubishi; it is capable of triggering nuclear reactions in condensed matter systems under modest temperatures and pressures
- ✓ Importantly, all of this experimental data is predicted and fully explained by the peer-reviewed Widom-Larsen theory of low energy nuclear reactions (LENRs)
- ✓ While the Mitsubishi permeation method is not a suitable embodiment for commercial power generation systems based on LENRs, it has proven to be an excellent laboratory tool for demonstrating that nuclear transmutations can be triggered at will without the use of huge macroscopic temperatures and pressures. In other words, aging stars, supernovae, fission reactors, and thermonuclear explosions are not necessarily required for nucleosynthesis to occur in tabletop experiments that surprisingly do not have or need any radiation shielding
- ✓ At the American Nuclear Society meeting in November 2012, Yasuhiro Iwamura of Mitsubishi revealed that the Toyota Motor company had recently become involved in LENR R&D, along with other large Japanese companies that he declined to name publicly. Given Japanese companies well known excellence at long-term strategic thinking, it would not be surprising if their ongoing LENR programs aim to ultimately replace the internal combustion engine

Mitsubishi's experimental method used since 2002

Cesium (Cs)

Praseodymium (Pr)

Reported various transmutations with this method

Lattice Energy LLC

Mitsubishi's experimental method used since 2002

Involves forced diffusion (permeation) of D_2/H_2 through Pd thin-film

Target elements implanted onto/into Pd film transmuted under mild conditions

Source for an author's copy: http://lenr-canr.org/acrobat/IwamuraYelementalaa.pdf

- ✓ In July 2002, Iwamura and colleagues at Mitsubishi Heavy Industries (Japan) first reported expensive, carefully executed experiments clearly showing nuclear transmutation of selected stable implanted target elements to other stable elements as detected via XPS analysis
- ✓ Experiments involved permeation of D_2 gas under 1 atm. pressure gradient at 343° K through a Pd:Pd/CaO thin-film heterostructure with Cs and Sr target elements placed on outermost Pd surface; electric current was not used to load Deuterium into Pd, only applied pressure differential, some heating, and time produced these results
- ✓ Results: Cs target is transmuted to Pr and Sr target transmuted to Mo
- ✓ Invoked Iwamura *et al.'s* EINR theory model (1998) to explain this data

> **Note:** Iwamura *et al*. make an interesting qualitative observation on pp. 4648 in the above paper, "…more permeating time is necessary to convert Sr into Mo than Cs experiments. In other words, Cs is easier to change than Sr."
>
> **Comment:** this observation is consistent with W-L theory neutron catalyzed transmutation; this result would be expected because Cs-133's neutron capture cross-section of 29 barns at thermal energies is vastly higher than Sr-88 's at 5.8 millibarns. *Ceteris paribus,* Cs transmutes faster simply because it captures neutrons more readily

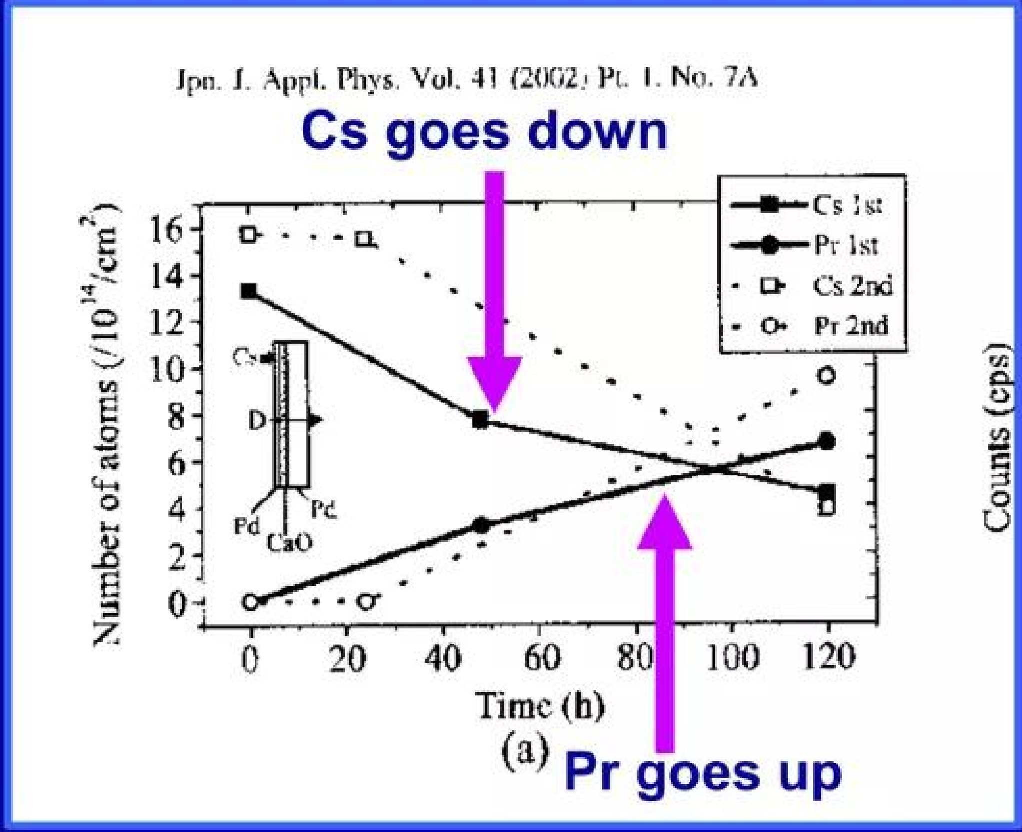
"Elemental analyses of Pd complexes: effects of D_2 gas permeation"
Y. Iwamura *et al.*
*Japanese Journal of Applied Phys*ics
41 pp. 4642 - 4650 (2002)

Central results were as follows:

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

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

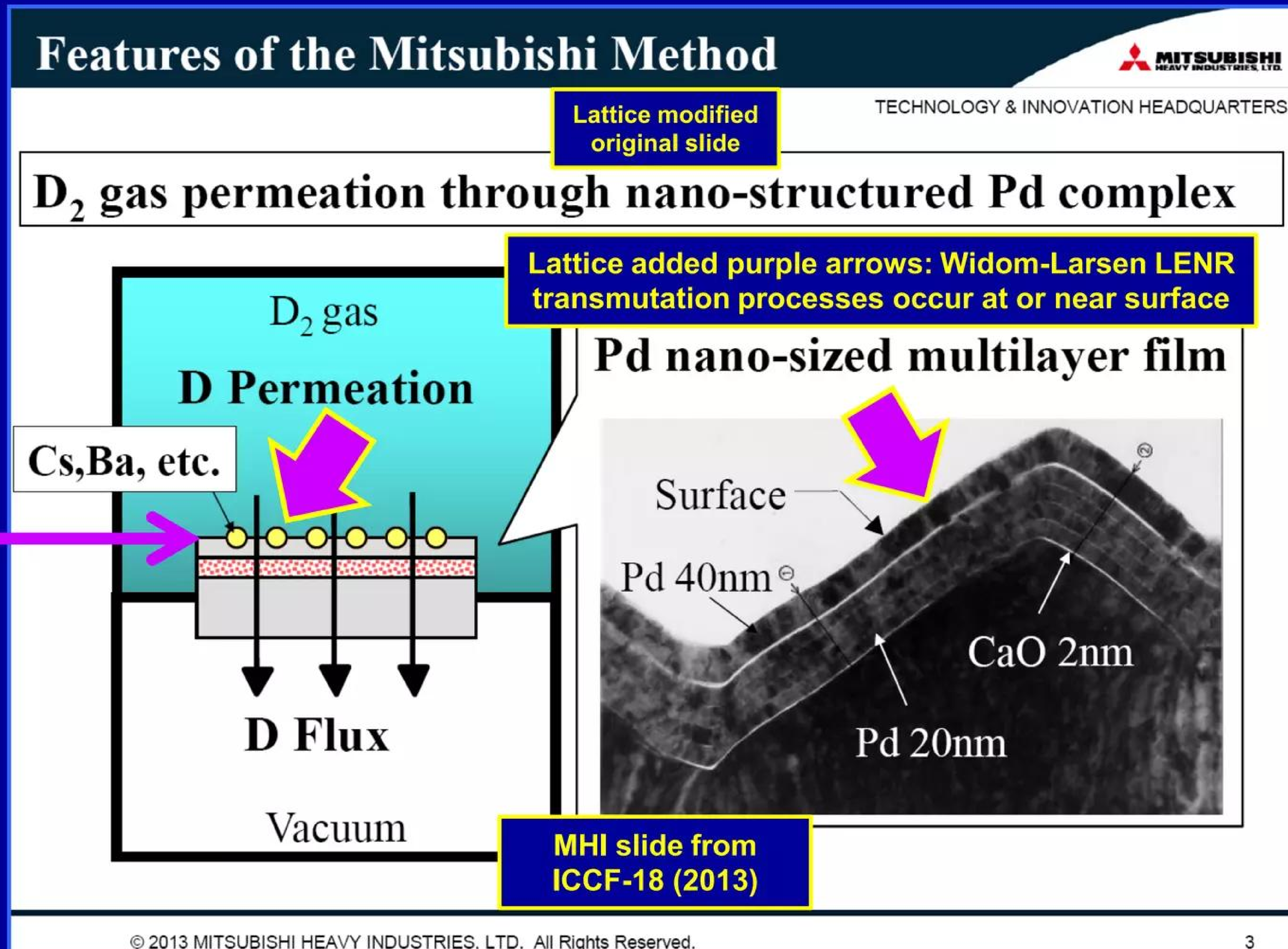
Isotopes on samples' surfaces analyzed in roughly real- time during the course of the experiments using XPS technique



Mitsubishi's experimental method used since 2002

Concept behind method presented in MHI slide from ICCF-18 (2013)

Cesium (Cs), Strontium (Sr), Barium (Ba), Calcium (Ca), and Tungsten (W) target elements are implanted onto or into Palladium (Pd) thin-film substrate layer

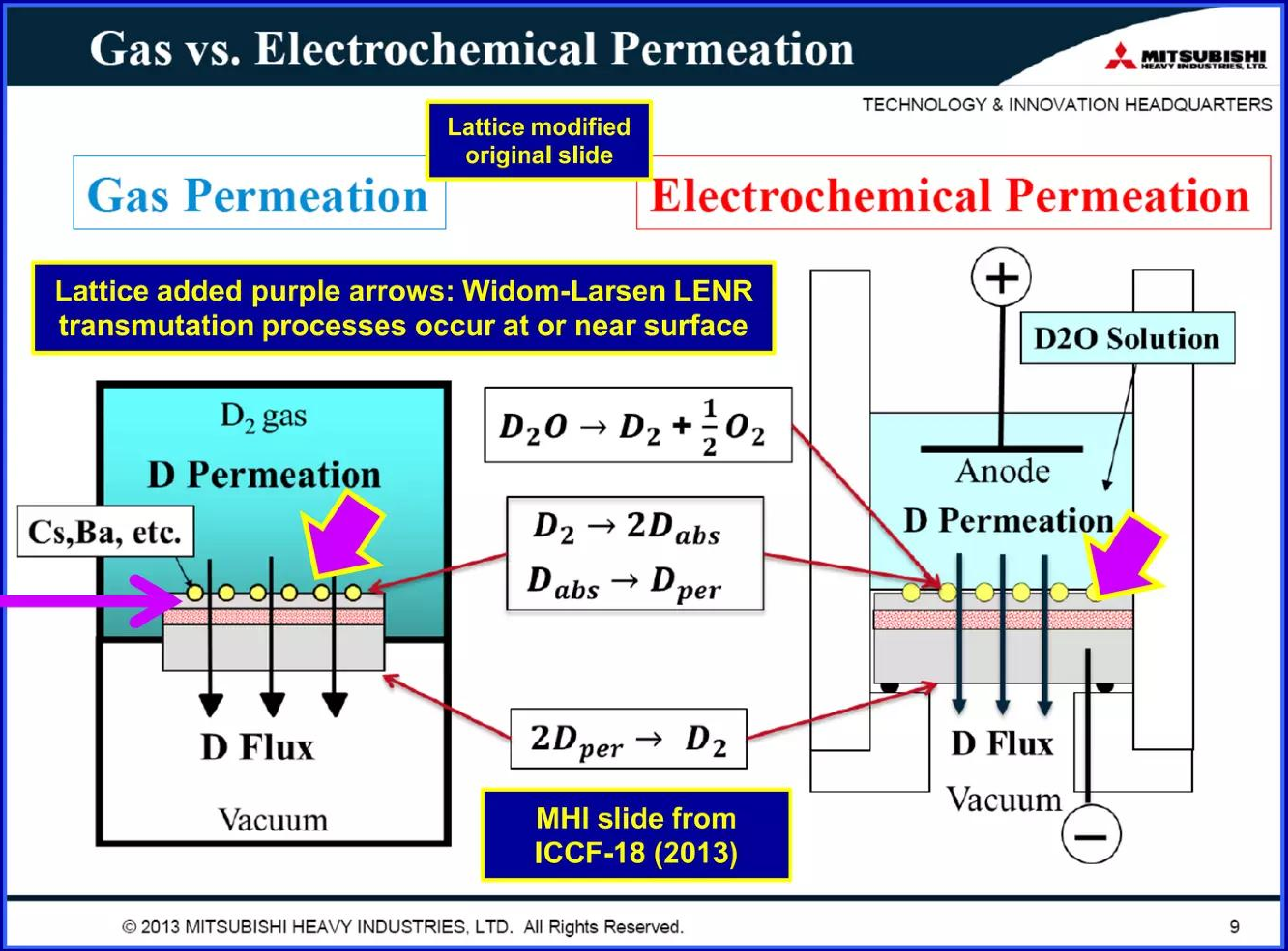


Source: https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/36792/RecentAdvancesDeuteriumPermeationPresentation.pdf?sequence=1

Mitsubishi's experimental method used since 2002

MHI compares their gas permeation method vs. electrochemical cells

Cesium (Cs), Strontium (Sr), Barium (Ba), Calcium (Ca), and Tungsten (W) target elements are implanted onto or into Palladium (Pd) thin-film substrate layer



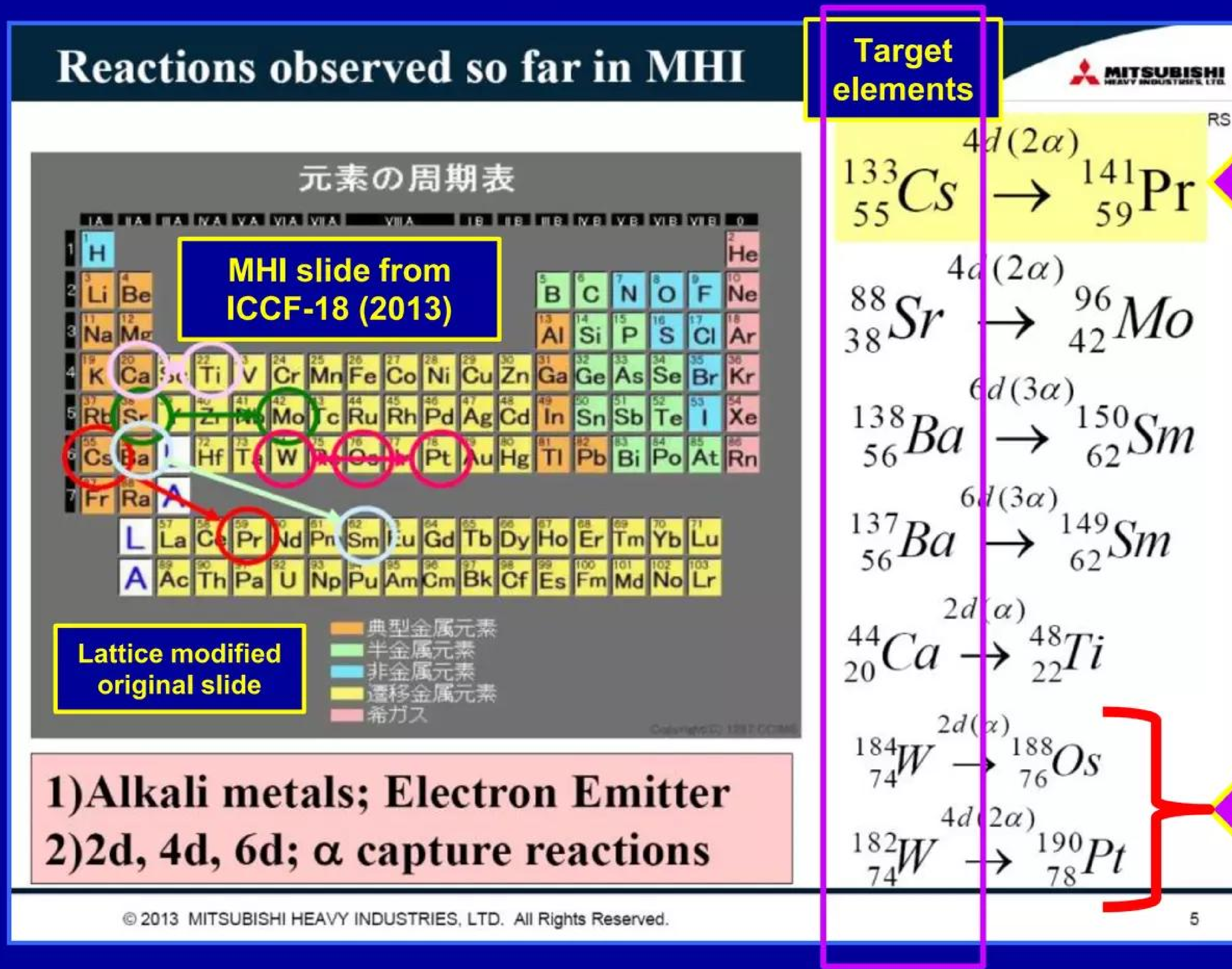
Source: https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/36792/RecentAdvancesDeuteriumPermeationPresentation.pdf?sequence=1

Mitsubishi's experimental method used since 2002

2013: MHI summarized LENR transmutation of targets reported to date

Widom-Larsen theory of LENRs explains all of these varied experimental results

Cesium (Cs), Strontium (Sr), Barium (Ba), Calcium (Ca), and Tungsten (W) target elements are implanted onto or into Palladium (Pd) thin-film substrate layer

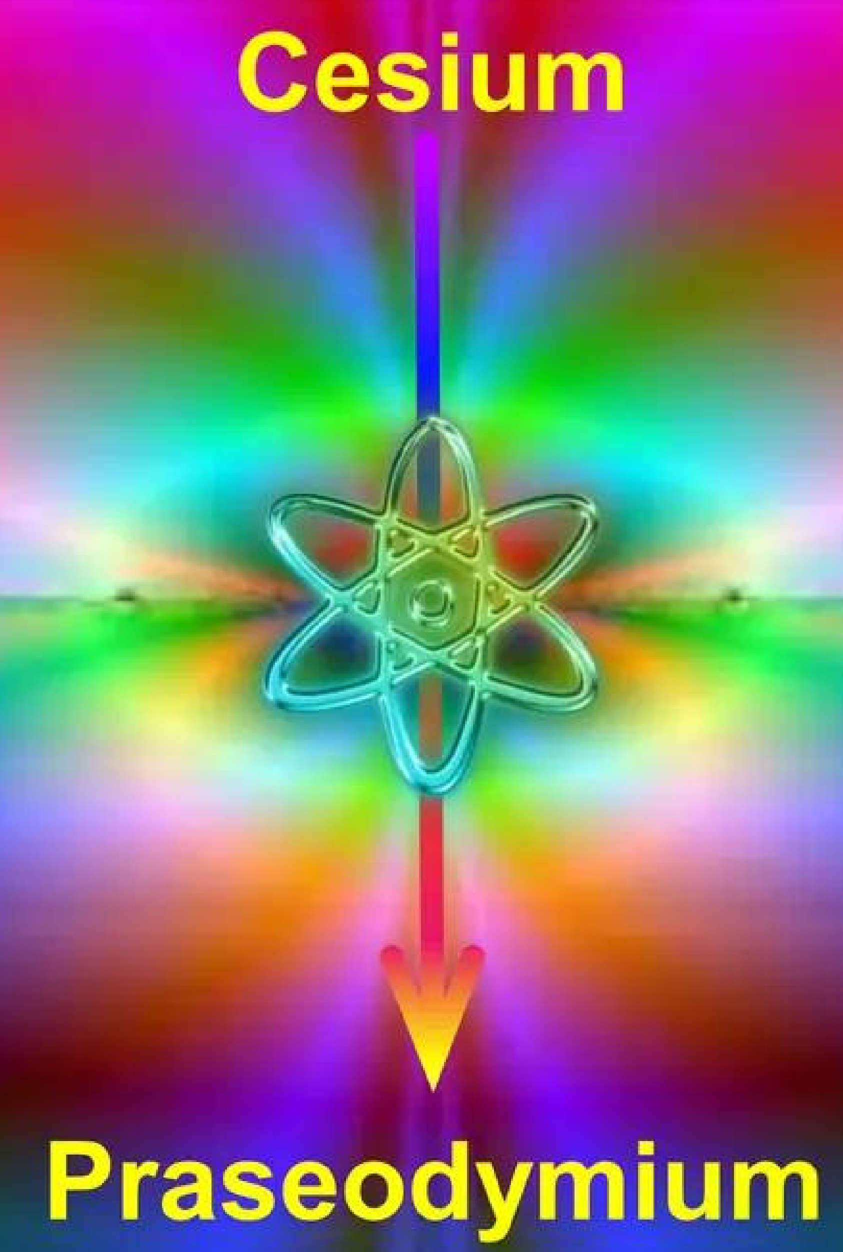


Confirmed by Toyota: *JJAP* (Oct. 2013)

Confirmed H. Nagaoka: *Nature* (1925)

Source: https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/36792/RecentAdvancesDeuteriumPermeationPresentation.pdf?sequence=1

Overview of the Widom-Larsen theory of LENRs



Many-body collective effects produce neutrons

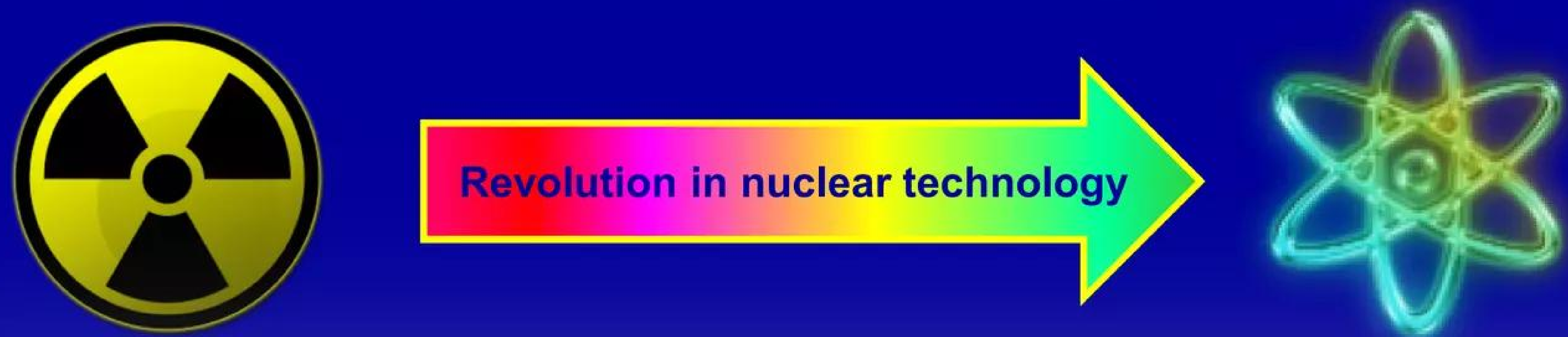
Lattice Energy LLC

Overview of the Widom-Larsen theory of LENRs

Hidden in plain sight for 100 years because no hard radiation emitted

Many-body collective QM effects enable nuclear reactions under mild conditions

LENRs are neither fission nor fusion but something rather different



Low energy nuclear reactions (LENRs) are a uniquely green nuclear technology: no deadly energetic gamma or neutron radiation and no production of long-lived radioactive wastes; enable development of bio-safe, very compact power systems

Overview of the Widom-Larsen theory of LENRs

LENR processes were effectively hidden in plain sight for 100 years

- ✓ Fusion (1929) and fission (1938) mainly rely on strong interaction and emit readily detectable fluxes of deadly MeV-energy gamma or energetic neutron radiation; consequently, those two types of nuclear processes were discovered experimentally and well-accepted by the physics and astronomy communities long before most recent public controversy about scientists claiming to have observed LENR transmutations in a prosaic electrolytic chemical cell (1989)

- ✓ In fact, observations of what we now know were actually LENRs have been episodically reported and published by experimentalists for nearly 100 years; however, given an absence of obvious hard radiation signatures, they had no Idea they were encountering a very green, energetic nuclear process that occurs on microscopic length-scales in condensed matter systems under a very particular set of conditions that only rarely line-up perfectly in Nature

- ✓ No radiological health risks are known to be associated with LENRs because they don't emit hard radiation and typically don't produce biologically significant amounts of environmentally hazardous, long-lived radioactive isotopes. That being the case, very subtle telltale signs of LENR activity can only be readily detected and measured through the use of extraordinarily sensitive, modern mass spectroscopy techniques on stable isotopes. Such analytical techniques have only been readily affordable and reasonably easy-to-use by a broad range of scientists in different disciplines for less than two decades. Consequently, LENR processes have effectively been hidden in plain sight and unappreciated by the vast majority of the world scientific community for the better part of the last 100 years

Overview of the Widom-Larsen theory of LENRs

Major paradigm shift in thinking about nucleosynthesis of elements

Collective many-body and quantum 'aikido' physics enable non-stellar process

- ✓ LENRs are an amazing neutron-catalyzed, hard radiation-free, star-like nucleosynthetic process that can operate at substantial rates in condensed matter systems at moderate macroscopic temperatures and under relatively low pressures; this is major paradigm shift in the physics of nucleosynthesis
- ✓ Condensed matter LENRs' neutron-catalyzed nucleosynthesis similar to both the s- and r-process that astrophysicists believe are responsible for creating elements heavier than Iron (Fe, A=56) in blazing-hot stars and in supernovae; unlike the s-/r-processes, however, experiments show LENRs can operate all the way from hydrogen up to the heaviest elements; another paradigm shift
- ✓ Nucleosynthesis of elements in Periodic Table is thus possible way outside super-hot stellar cores and violently exploding stars; this is a profound paradigm shift from what astrophysicists previously believed was possible
- ✓ Non-stellar nucleosynthesis in otherwise comparatively benign physical environments is enabled by Widom-Larsen physics *aikido* explained herein

Lattice Energy LLC

Overview of Widom-Larsen theory of LENRs

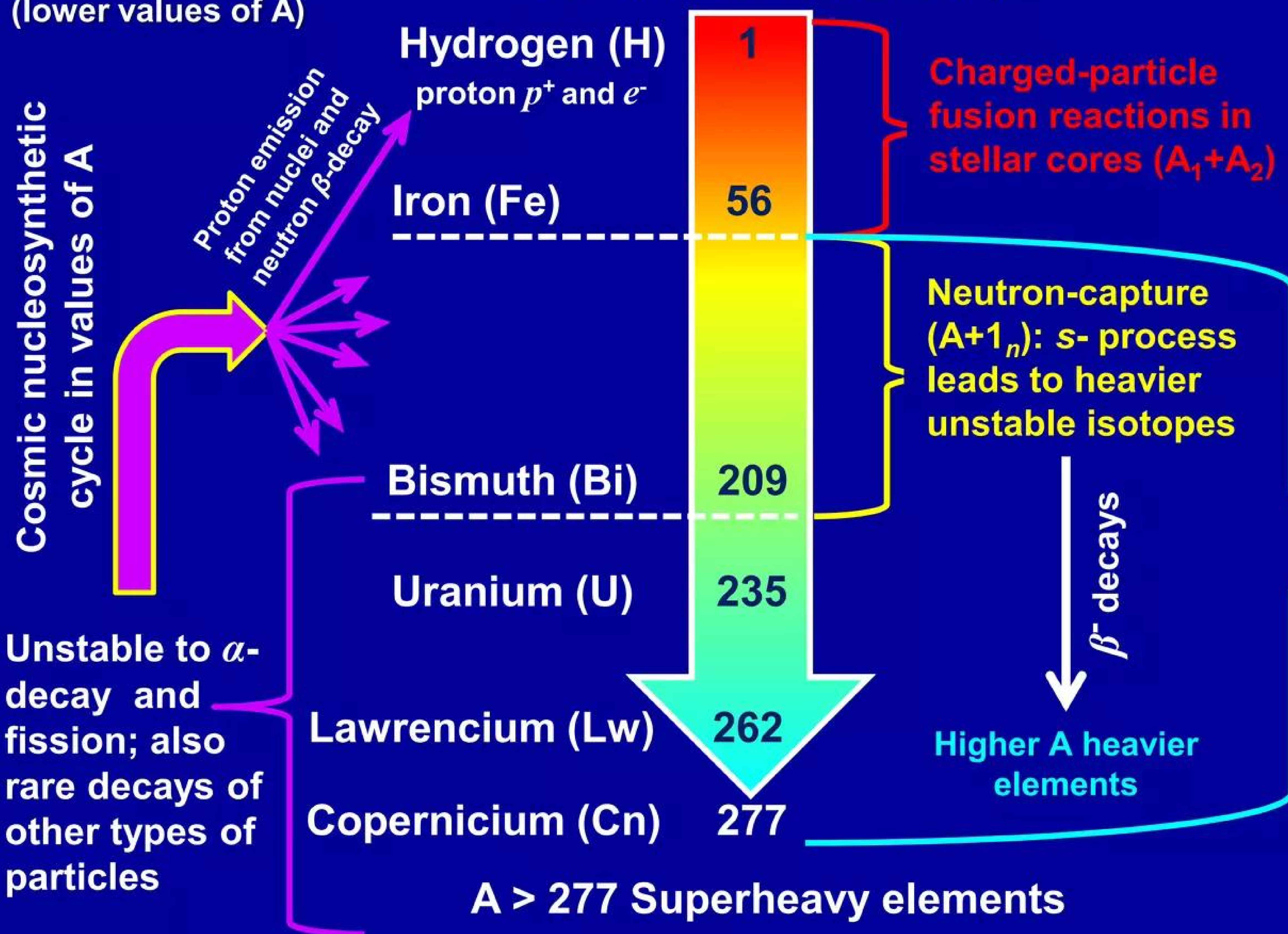
Summarizes astrophysicists' present beliefs about nucleosynthesis

LENR transmutation networks capable of making any element in Periodic Table

Fission and α-decay processes recycle heavy elements back into lighter ones (lower values of A)

Atomic Mass (A)

Note: number of protons in nucleus determine + charge and the element's atomic number (Z)



Different elements all have different atomic numbers (Z); a given element may have >1 stable and unstable isotopes that differ in A (total number of neutrons + protons = A). Today, there are 112 recognized elements (heaviest is Copernicium: Z = 112, A = 277, H.L. = 29 sec) and over 3,000 known stable and unstable isotopes

Fusion reactions occur deep in cores of stars; *s*-process thought to occur in outer envelopes of late-stage red giant stars; as of today, while most believe *r*-process occurs in supernova explosions, nobody is 100% certain that presumption is true

Neutron-capture (A+1_n): *r*-process

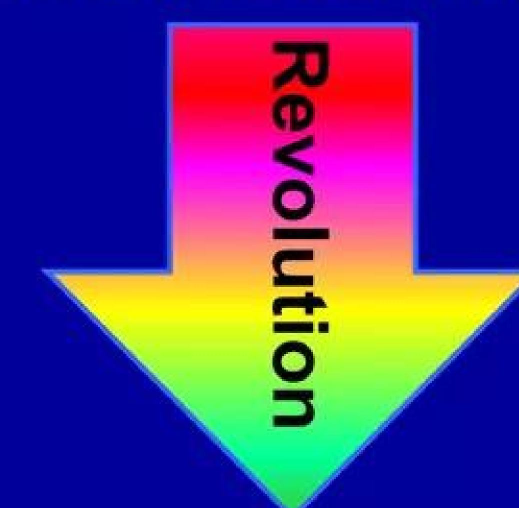
Beta-decay: unstable, neutron-rich isotopes generally decay via the beta-minus (β^-) decay process; this converts a neutron (*n*) into a proton; atomic number increases by +1 which creates a stable or unstable isotope of a *different* element; value of A is essentially unchanged

Overview of Widom-Larsen theory of LENRs

Brief history of theory's publication timeline and present status

- ✓ **1896:** Becquerel discovered radioactivity (France)
- ✓ **2001:** Lattice received seed funding from private investors and began operating in Chicago, IL
- ✓ **2005:** Cornell arXiv preprint provided first truly rigorous theory of LENRs with key features based on weak interaction and many-body collective effects under umbrella of Standard Model; no "new physics" found anywhere in Widom-Larsen theory publications
- ✓ **2006:** core elements of our theory explained in paper by Widom & Larsen published in the peer-reviewed *European Physical Journal C – Particles and Fields*
- ✓ **2010:** paper summarizing entire sweep of W-L theory was published in *Pramana - Journal of Physics*
- ✓ **2013:** basic science and proprietary aspects of device physics have finally been worked-out; LENRs are now ready for device engineering and commercialization

Fusion and fission both occur in Nature



Green LENRs

Lattice Energy LLC

Overview of Widom-Larsen theory of LENRs

Key papers published in peer-reviewed academic physics journals

Paper	Subject matter
"Ultra low momentum neutron catalyzed nuclear reactions on metallic hydride surfaces" A. Widom and L. Larsen, *European Physical Journal C - Particles and Fields* 46 pp. 107 - 112 (2006) Author's copy: note - first uploaded to the arXiv in May 2005 http://www.slideshare.net/lewisglarsen/widom-and-larsen-ulm-neutron-catalyzed-lenrs-on-metallic-hydride-surfacesepjc-march-2006	Except for gamma suppression, all core concepts of W-L theory and key details of its weak interaction physics found in this refereed paper; includes upward mass-shifting of SP electrons, B-O breakdown, etc. ; gamma conversion in Sept. 2005
"Absorption of nuclear gamma radiation by heavy electrons on metallic hydride surfaces" A. Widom and L. Larsen (Sept 2005) http://arxiv.org/PS_cache/cond-mat/pdf/0509/0509269v1.pdf	Covers W-L theory of hard gamma photon absorption and conversion to infrared in condensed matter LENRs
"Nuclear abundances in metallic hydride electrodes of electrolytic chemical cells" A. Widom and L. Larsen (Feb 2006) http://arxiv.org/PS_cache/cond-mat/pdf/0602/0602472v1.pdf	Explains Miley transmutation data with Widom-Larsen optical model of ULM neutron absorption in condensed matter
"Theoretical Standard Model rates of proton to neutron conversions near metallic hydride surfaces" A. Widom and L. Larsen (v2. Sep 2006) http://arxiv.org/PS_cache/nucl-th/pdf/0608/0608059v2.pdf	Theoretical calculations of W-L ULM neutron production rates; agrees well with best available experimental measurements
"Energetic electrons and nuclear transmutations in exploding wires" A. Widom, Y. N. Srivastava and L. Larsen (Sept 2007) http://arxiv.org/PS_cache/arxiv/pdf/0709/0709.1222v1.pdf	W-L theory of weak interactions applied to high-current exploding wires; explains Wendt-Irion experimental data (1922)
"Errors in the quantum electrodynamic mass analysis of Hagelstein and Chaudhary" A. Widom, Y.N. Srivastava and L. Larsen (Feb 2008) http://arxiv.org/PS_cache/arxiv/pdf/0802/0802.0466v2.pdf	Hagelstein & Chaudhary published their criticism of W-L theory; our response clearly refuted all of their arguments
"High energy particles in the Solar corona" (April 2008) A. Widom, Y.N. Srivastava and L. Larsen http://arxiv.org/PS_cache/arxiv/pdf/0804/0804.2647v1.pdf	Applies many-body collective, magnetically dominated W-L theory to explain the anomalous heating of the solar corona
"A primer for electro-weak induced low energy nuclear reactions" Y. N. Srivastava, A. Widom and L. Larsen, *Pramana - Journal of Physics* 75 pp. 617 - 637 (2010) http://www.ias.ac.in/pramana/v75/p617/fulltext.pdf	Summarizes all of the W-L theoretical concepts found in previous 6 papers at slightly lower levels of mathematical detail
Note: initial versions of all these papers are available online at the Cornell physics preprint arXiv	

Lattice Energy LLC

Overview of Widom-Larsen theory of LENRs

Operates from the microcosm to the astrophysical macrocosm

Characteristic LENR length scales range from *nm* to *µ* in condensed matter

	Length Scale	Type of System	Electromagnetic Regime	Collective LENR Phenomena	Comment
Green nuclear regime	Submicron	Certain earthly bacteria and fungi	Very short-range electric or magnetic fields	Transmutations, high level gamma shielding	Obtain unavailable trace elements; survive deadly gamma/X-ray radiation
	Microns	Hydrogen isotopes on metallic surfaces	Very high, short-range electric fields on solid substrates	Transmutations, high level gamma shielding, heat, some energetic particles	This regime is useful for small-scale commercial power generation
	Microns to Many Meters	Exploding wires, planetary lightning	Dusty plasmas: mixed high-current and high local magnetic fields	Transmutations, 'leakier' gamma shielding, heat; X-rays up to 10 keV, larger energetic particle fluxes	This regime is useful for large-scale commercial power generation
Magnetically dominated regime	Many Meters to Kilometers	Outer layers and atmospheres of stars (flux tubes)	Dusty plasmas: high mega-currents and very large-scale, highly organized magnetic fields	Transmutations, large fluxes of energetic particles (to GeVs), limited gamma shielding, X-rays	Solves mysteries of heating of solar corona and radioactive isotopes in stellar atmospheres
	Up to several AU (distance from earth to sun)	Active galactic nuclei in vicinity of compact, massive objects (black holes)		Energetic particles (GeVs), gamma-ray bursts (GRBs) and ultra-high energy cosmic rays (TeVs)	Solves several unexplained astronomical mysteries

Note: mass renormalization of electrons by high local E-fields not a key factor in magnetically dominated regimes at large length scales

Lattice Energy LLC

Overview of Widom-Larsen theory of LENRs

Operates from the microcosm to the astrophysical macrocosm

Short-Range Collective Electric Field Effects Dominate

Longer-Range Collective Magnetic Field Effects Begin to Dominate

Long-Range Collective Magnetic Field Effects Dominate

Collective nuclear aikido

Many-body collective magnetic taekwondo

Regime of mostly *very* low energy neutron reactions: LENRs dominate

W-L: $e^* + p^+ \rightarrow$ 1 neutron + neutrino **or** $e^* + d^+ \rightarrow$ 2 neutrons + neutrino

Neutron production and capture release energy, create transmutation products

Low to medium electric and/or ion currents

- Microorganisms - biological transmutations by some types of earthly bacteria and fungi
- Pressure gradients across membranes - e.g., Iwamura, Arata (Japan); Li (China); gas phase
- Current-driven P&F-type chemical cells - liquid phase; glow discharge cells - gas phase
- Laser-triggered chemical cells - e.g., Letts & Cravens; Violante, Barmina; liquid/gas phase
- RF-triggered dusty plasmas - e.g., Mills (USA); Univ. of Florida in 1960s (USA); gas phase

High currents: electrons and/or ions

- Current-driven dusty plasmas; gaseous phase only (literature mainly within last 15 years)
- Vacuum diodes - e.g., Proton-21 (Ukraine); Sandia N.L. (USA) in mid-1970s; gas phase only
- Exploding wires - e.g., Wendt & Irion 1922 (USA); Z-pinch at Sandia N.L. (USA); gas phase
- Magnetic flux compression generators - e.g., Los Alamos N.L. (USA); institutes in Russia
- Lightning (terrestrial, planetary, nebular), especially in dusty environments - e.g., Dwyer
- ULMN-catalyzed subcritical fission reactors (<<< nuclear waste) - reprocess stored wastes

Higher fluxes of neutrons

Scales-up to very large length scales | Wide range of magnetic field strengths

W-L mixed regime: high energy particle reactions and/or LENRs on dust

Mega-scale currents

Magnetic effects dominate large length-scale plasmas: $e^- + p^+ \rightarrow$ lepton + X

- Stars: additional nuclear reactions occur in photospheres, flares, and further out in coronas
- Dusty, hydrogen-rich nebular plasma clouds exposed to stellar photon and particle radiation
- Magnetars/active galactic nuclei: W-L mechanism can in theory create UHE TeV cosmic rays

>>>> fluxes

~0 eV Ultra low momentum neutrons .... MeV neutrons ...GeV neutrons ....TeVs

Increasing neutron and charged particle energies

Lattice Energy LLC

Overview of Widom-Larsen theory of LENRs

Explains why LENRs are an intrinsically green nuclear process

Prerequisite basic underlying science is now well-understood and published

- ✓ In 1989, small group of researchers thought LENRs were form of "cold fusion"
- ✓ These researchers were dead wrong: thanks to Widom-Larsen theory (WLT) we now know that unique features of LENRs instead involve the weak interaction, not strong interaction fusion (hot, cold, warm, or otherwise) or nuclear fission
- ✓ WLT explains exactly how LENRs are clean and environmentally green, i.e., why there are no deadly emissions of MeV-energy gamma photon radiation, fluxes of dangerous energetic neutrons, or production of large quantities of long-lived radioactive isotopes --- no shielding or containment are required
- ✓ As of today, we have published the non-proprietary, basic physics of LENR devices in two mainstream peer-reviewed physics journals (2006, 2010)
- ✓ While vast majority of competitors may still be struggling to understand basic science issues in LENRs, after 12 years of effort Lattice is now ready to apply its proprietary knowledge of LENRs and begin a device engineering program to build ultra-high performance portable and stationary clean power generators

Overview of the Widom-Larsen theory of LENRs

Synopsis and comparison of four key types of energy technologies

Combustion of fossil fuels (strictly chemical processes involving outer valence electrons of nuclei):

Comments: emits copious quantities of CO_2, a greenhouse gas; comprises vast majority of mankind's energy production today

Scale of energy release: eVs (chemical regime)

Alternate natural sources of fuel: primarily oil, coal, and biomass; basic reaction: $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$ + energy

Controlled release of nuclear binding energy (fission and fusion; mainly involve strong interaction):

Comments: no CO_2 emission; emit dangerous *energetic* radiation (γ, neutron); today <10% of global energy production

Scale of energy release: MeVs (nuclear regime) > 1,000,000x all chemical energy sources

Heavy-element fission (involves shattering heavy nuclei to release stored nuclear binding energy):

Comments: requires massive shielding and containment structures to handle radiation; major rad-waste clean-up

Alternate natural sources of fuel: today, almost entirely Uranium; Thorium-based fuel cycles now under development

Heavy element U-235 (fissile isotope fuel) + neutrons → (complex array of lower-mass fission products; some are very long-lived isotopes) + energetic gamma radiation + energetic neutron radiation + energy

Fusion of light nuclei: (involves smashing light nuclei together to release stored nuclear binding energy):

Comments: present multi-billion $ development efforts (e.g., ITER, NIF, Tokamaks) focusing mainly on D+T fusion reaction; requires massive shielding/containment structures to handle 14 MeV neutron radiation; minor rad-waste clean-up $ vs. fission

Natural sources of fuel: Deuterium and Tritium (two heavy isotopes of hydrogen)

Most likely commercial fusion reaction involves: D + T → He-4 (helium) + neutron + energy (total 17.6 MeV; ~14.1 MeV in neutron)

Low energy neutron reactions (LENRs - key distinguishing feature is neutron production via weak interaction; neutron capture + gamma conversion to IR + decays [α, β] release nuclear binding energy):

Comments: early-stage technology; no emission of energetic neutron or gamma radiation; no long lived rad-waste products; LENR systems do not require massive and expensive radiation shielding and containment structures → much lower $ cost

Natural sources of fuel: *any* element/isotope that can capture LE neutrons and release >0.78 MeV in nuclear binding energy

Involves complex, branching LENR nucleosynthetic transmutation networks that begin with neutron captures on seed nuclei then proceed from lower to higher values of atomic mass (A); very similar to what happens in stars, only at low temps/pressures

Lattice Energy LLC

Overview of Widom-Larsen theory of LENRs

LENRs intrinsically greener than fission or fusion processes

Absence of shielding and containment issues enables portable nuclear power

- ✓ Good news about CO_2-free Uranium and Plutonium fission reactions is that they have Q_v values of ~190^+ MeV, releasing most of their energy on a time scale of ~10^{-19} seconds in the form of prompt neutron and gamma radiation as well as fast moving, neutron-rich, asymmetric fission fragments comprising unstable products that undergo further decays; bad news is they produce large fluxes of deadly MeV neutron and gamma radiation as well as long-lived radioactive wastes; massive shielding/containment is mandatory for reactors

- ✓ Good news about cleaner (vs. fission) CO_2-free D-T fusion reactions in commercial power reactors is Q_v of ~17.6 MeV; bad news is that most of the binding energy released is in the form of hard-to-manage 14.1 MeV neutrons along with gamma rays and neutron-induced radioactivity in apparatus; huge temps, 'fast' neutrons create major engineering problems

- ✓ Good news about CO_2-free LENR transmutation processes is that they do not produce biologically significant quantities of deadly gamma or neutron radiation or hazardous long-lived radioactive isotopes; in contrast to fission or fusion - no bad news for LENRs

- ✓ Many scientists mistakenly believe that weak interactions are weak energetically; that view is incorrect. In a Carbon-target LENR transmutation network, neutron-rich Nitrogen-17 and Nitrogen-18 $beta^-$ decays release 22.8 and 23.8 MeV, respectively; this is comparable to nuclear fusion reactions but without any need for enormous temperatures or pressures. Little or no shielding, containment, or clean-up would be needed for LENR power systems

Lattice Energy LLC

Overview of Widom-Larsen theory of LENRs

Some LENRs energetically comparable to fusion reactions

Fission and fusion are few-body taekwondo; LENRs are many-body aikido

Less Energy Per Reaction

Reaction Type	Typical "Average" Energy Release		Relative Index of Energy Release	
U-235 Conventional Fission (1938)	220 MeV	Nuclear: Strong Interaction	1000	Taekwondo
H+H Fusion in Stars (1939)	27 MeV		123	
D+T Fusion Reactors (1950s)	17. 6 MeV		80	
Light and Heavy Water LENRs (1989)	~ 22 MeV (high side)	Nuclear: Weak Interaction	91	Aikido
	~ 0.1 MeV (low side)		0.45	
Blacklight Power's "Hydrinos" (1991)	max 0.02 MeV	?	0.09	Chemical
Hydrogen Fuel Cells (1838)	0.0002 MeV	Chemical	0.0001	
Combustion of Gasoline (1876)	0.0001 MeV		0.00005	

Evolution of nuclear technology

Lattice Energy LLC

Overview of Widom-Larsen theory of LENRs

Collective LENR processes utilize energy from many SP electrons

Many-body collective nuclear reactions do not require super-hot temperatures

- ✓ **SP electron mass-renormalization by absorbing E-M energy directly from a local electric field allows a portion of the SP electrons sitting in a tiny LENR-active patch to possess enough additional mass-energy (>0.78 MeV) to cross energetic threshold for reacting directly with local coherent protons or deuterons to make neutrons and neutrinos; SP electrons do not have to be at high macroscopic temps to do this = aikido physics**

- ✓ **Comparatively cool, collective many-body aikido field-energy process in condensed matter LENRs contrasts sharply with few-body taekwondo kinetic processes that occur in stellar, tokamak, *Z*-pinch, and ICF fuel target fusion plasmas where charged particles, e.g. d^+ and t^+, are heated to enormous temperatures so a small subset (high-energy tail of Maxwellian distribution of particle energies) of them that strike each other head-on have enough kinetic energy to surmount the Coulomb energetic barrier (like charges repel each other) to nuclear fusion reactions**

Overview of Widom-Larsen theory of LENRs

Condensed matter LENR processes mainly involve these reactions

Many-body collective quantum effects permit this under non-stellar conditions

Collective effects + input energy = aikido:

$\text{Energy}_{\text{E-field}} + e^{-}_{sp} \rightarrow e^{-*}_{sp} + p^{+} \rightarrow n + \nu_e$

$\text{Energy}_{\text{B-field}} \rightarrow e^{-} + p^{+} \rightarrow lepton + X$ [magnetic regime]

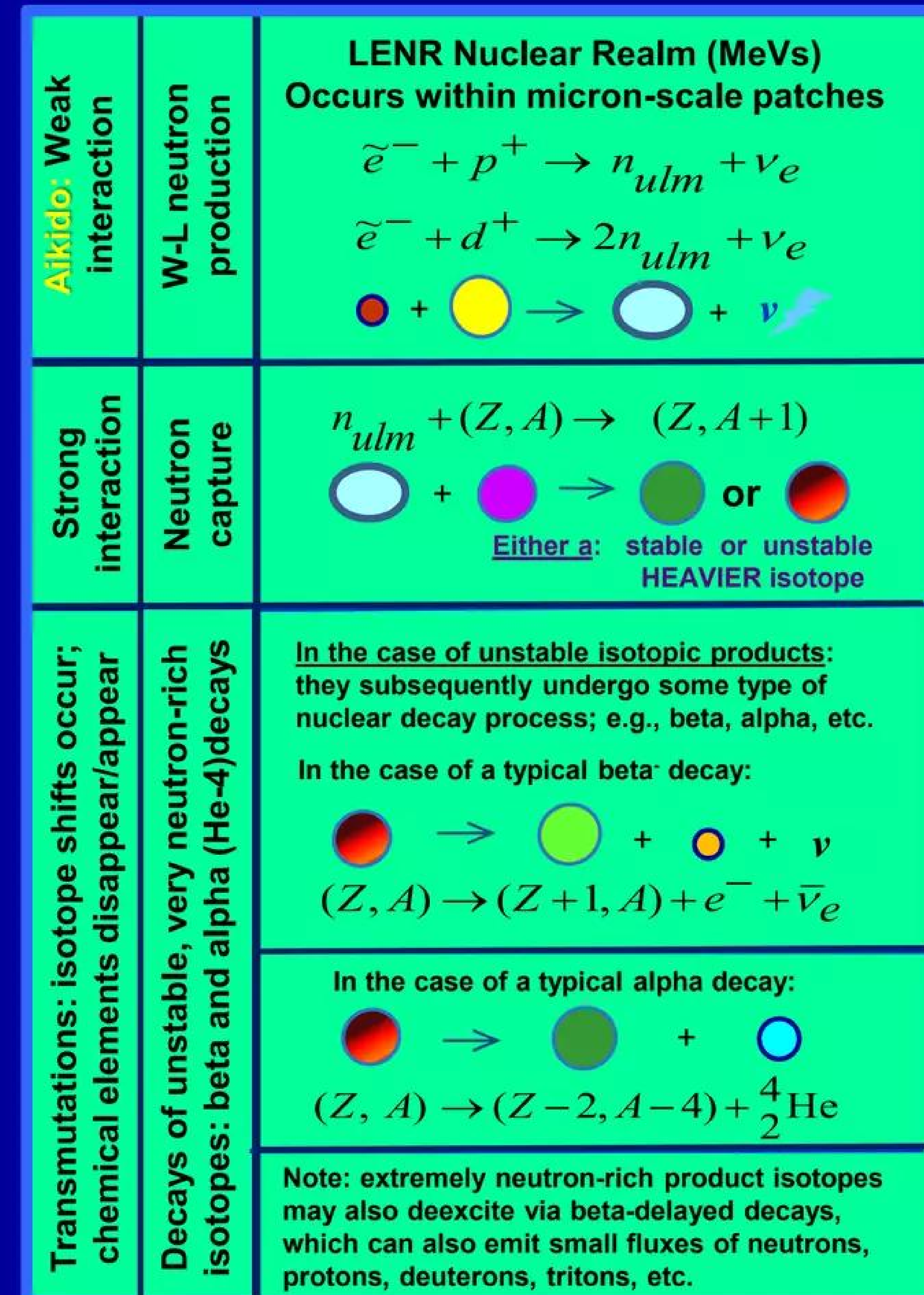
Collective electroweak production of neutrons in condensed matter and large-scale magnetic regimes

Afterwards, neutrons capture on targets:

$n + (Z, A) \rightarrow (Z, A+1)$ [neutron capture on targets]

$(Z, A+1) \rightarrow (Z + 1, A+1) + e_{\beta}^{-} + \nu_e$ [beta⁻ decay]

Mainly β^{-} decays of neutron-rich isotopic products



Overview of Widom-Larsen theory of LENRs

Condensed matter LENR processes mainly involve these reactions

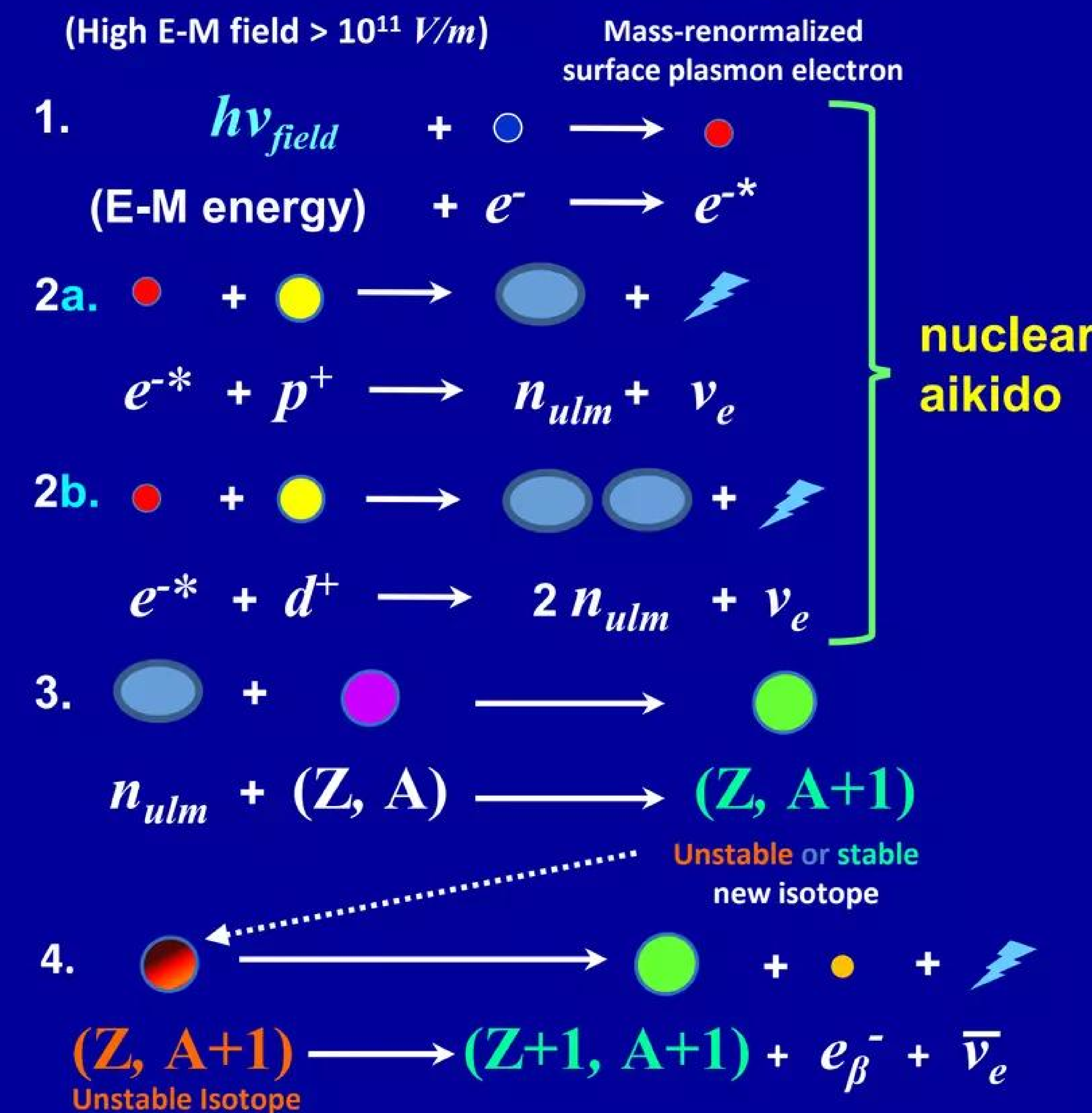
In condensed matter systems, Steps 1. through 4. occur in nm- to μ-sized patch regions on surfaces; these are called LENR-active sites

Steps 1. thru 3. are very fast: can complete in 2 to 400 nanoseconds

1. Electromagnetic (E-M) radiation on a metallic hydride surface increases mass of surface plasmon (SP) electrons
2. Heavy-mass surface plasmon electrons react directly with (a) surface protons (p^+) or (b) deuterons (d^+) to produce ultra low momentum (ULM) neutrons (n_{ulm} or 2 n_{ulm}, respectively) and an electron neutrino (v_e)
3. Ultra low momentum neutrons (n_{ulm}) are captured by nearby atomic nuclei (Z, A) representing some element with charge (Z) and atomic mass (A). ULM neutron absorption produces a heavier-mass isotope (Z, A+1) via transmutation. This new isotope (Z, A+1) may itself be a stable or unstable, which will perforce eventually decay
4. Many unstable isotopes β^- decay, producing: transmuted element with increased charge (Z+1), ~same mass (A+1) as parent nucleus; β^- particle (e_β^-); and an antineutrino v_e

Ultra low momentum neutrons are almost all captured locally (very few have time to thermalize and be detected); any gammas produced get converted directly to infrared photons (heat) by heavy electrons

No strong interaction fusion or heavy element fission occurring below; weak interaction $e + p$ or $e + d$



Weak interaction β^- decays (shown just above), direct gamma conversion to infrared photons (not shown), and α decays (not shown) produce most of the excess heat that is calorimetrically observed in LENR systems

Overview of Widom-Larsen theory of LENRs

Nuclear-strength local E-fields needed to shift electron masses

Local quantum entanglement of patch SP electrons and protons is crucial

- ✓ **Ultra low momentum (ULM) neutron production can begin in given many-body patch of protons sometime after local E-field strengths exceed ~2 x 10^{11} V/m (i.e., e^{-*} mass renormalization ratio β is now greater than minimum threshold ratio β_0) and adequate numbers of mass-renormalized e^{-*} electrons have been created (enabled by local breakdown of Born-Oppenheimer approximation in ~temporal conjunction with nonequilibrium energy inputs)**

- ✓ **Key $e^{-*} + p^{+}$ or $e^{-*} + d^{+}$ weak reactions must necessarily occur during many-body, collectively oscillating protons' brief moments of quantum coherence (i.e., effective entanglement within a patch); duration of such proton coherence times are on the order of attoseconds (~10^{-18} sec); these times have been measured by Chatzidimitriou-Dreismann, 2005, cited in Slide #44 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewpahs-and-lenrsnov-25-2009**

- ✓ **After the e^{-*} mass renormalization set-up process has completed and heavy e^{-*} electrons and p^{+} protons are heavy-enough to react (i.e., β now > β_0), subsequent weak reactions that follow only require ~10^{-19} to 10^{-22} sec to finish. Thus, while flickering proton coherence times are relatively short, weak $e^{-*} + p^{+}$ reactions that produce ULM neutrons operate on much faster *nuclear* time-scales; this allows collective neutron production to proceed at substantial rates**

- ✓ **When collectively produced neutrons are ULM, local neutron capture processes occur over time-horizons on the order of picoseconds (10^{-18} sec); not enough time for them to thermalize**

Overview of Widom-Larsen theory of LENRs

Appropriate forms of input energy required to produce neutrons

Electron or ion currents, incoherent or laser photon fluxes, and magnetic fields

- ✓ **Input energy is required:** to create non-equilibrium conditions that enable nuclear-strength local E-fields which produce populations of heavy-mass e^{-*} electrons that react with many-body surface patches of p^+, d^+, or t^+ to produce neutrons via $e^{-*} + p^+ \rightarrow 1\ n$ or $e^{-*} + d^+ \rightarrow 2\ n$, etc. (cost = 0.78 MeV/neutron for H; 0.39 for D; 0.26 for T); includes (can be combined):
  - **Electrical currents** - i.e., an electron beam of one sort or another can serve as input source
  - **Ion currents** - across the interface on which SP electrons reside (i.e., an ion beam that can be comprised of protons, deuterons, tritons, and/or other types of charged ions); one method used to input energy is ion flux caused by imposing a pressure gradient (Iwamura *et al.* 2002)
  - **Incoherent and coherent E-M photon fluxes** - can be incoherent E-M radiation found in resonant electromagnetic cavities; with proper coupling, SP electrons can also be directly energized with coherent laser beams emitting photons at appropriate resonant wavelengths
  - **Organized magnetic fields with cylindrical geometries** - mainly at very high electron currents; includes organized, non-ideal so-called dusty plasmas --- scales way-up to stellar flux tubes
- ✓ **Key feature of complex multi-step LENR transmutation networks:** large numbers of viable network pathways can release more net nuclear binding energy that arises from a combination of neutron captures (with direct conversion of resulting prompt and delayed gammas into IR per W-L theory) and nuclear decays (e.g., α, β, etc.) vs. input energy that is required to produce total numbers of neutrons required for network pathway(s) to operate

Lattice Energy LLC

Overview of Widom-Larsen theory of LENRs

Following conditions required to energize and sustain LENRs

All of these requirements must be fulfilled to trigger neutron production

- ✓ Substantial quantities of Hydrogen isotopes must be brought into intimate contact with fully-loaded metallic hydride-forming metals (or non-metals like Se); e.g., Palladium, Platinum, Rhodium, Nickel, Titanium , Tungsten, etc. Please note that collectively oscillating, 2-D surface plasmon (SP) electrons are intrinsically present and cover the surfaces of such metals. At 'full loading' of H, many-body, collectively oscillating island-like 'patches' of protons (p^+), deuterons (d^+), or tritons (t^+) will form spontaneously at random locations scattered across such surfaces

- ✓ Or, delocalized collectively oscillating π electrons that comprise the outer covering surfaces of fullerenes, graphene, benzene, and polycyclic aromatic hydrocarbon (PAH) molecules behave very similarly to SPs; when such molecules are hydrogenated, they can create many-body, collectively oscillating, entangled quantum systems that, per W-L theory, are functionally equivalent analogues of loaded metallic hydrides (trigger LENRs on aromatic rings)

- ✓ Born-Oppenheimer approximation breaks down in tiny surface patches of contiguous collections of collectively oscillating p^+, d^+, and/or t^+ ions; enables E-M coupling between nearby SP or π electrons and hydrogen ions at these locations; creates nuclear-strength local electric fields > 2 x 10^{11} V/m; effective masses of electrons in that field are then increased to a multiple of an electron at rest ($e \rightarrow e^*$) - determined by required ~simultaneous energy input(s)

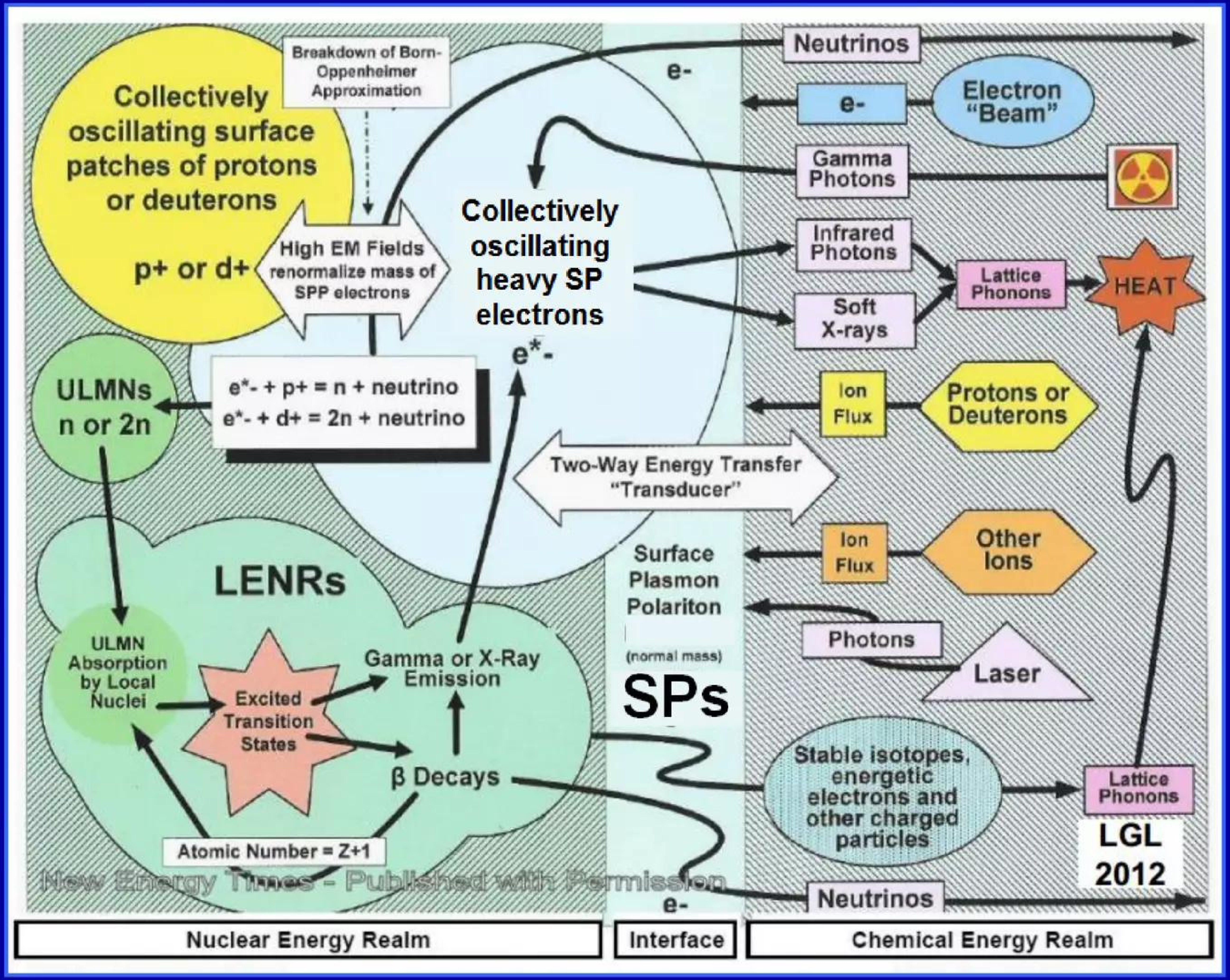
- ✓ System must be subjected to external non-equilibrium fluxes of charged particles or E-M photons that are able to transfer input energy directly to many-body SP or π electron surface films. Examples of such external energy sources include (they may be used in combination): electric currents (i.e., electron beams); E-M photons (e.g., emitted from lasers, IR-resonant E-M cavity walls, etc.); pressure gradients of p^+, d^+, and/or t^+ ions imposed across surfaces; currents of other ions crossing the SP electron surface in either direction (ion beams); etc. Such sources can provide additional input energy required to surpass certain minimum H-isotope-specific electron-mass thresholds that allow production of ULM neutron fluxes via $e^* + p^+$, $e^* + d^+$, or $e^* + t^+$ weak interactions

- ✓ N.B.: please note again that surface plasmon electrons are collective, many-body electronic phenomena closely associated with interfaces. For example, they can exist at gas/metal interfaces or metal/oxide interfaces. Thus, surface plasmon oscillations will almost certainly also be present at contact points between purely metallic surfaces and adsorbed target nanoparticles composed of metallic oxides, e.g., PdO, NiO, or TiO_2, etc., or vice-versa

Lattice Energy LLC

Overview of Widom-Larsen theory of LENRs

Overview of W-L and LENR processes in condensed matter systems



Overview of Widom-Larsen theory of LENRs

Heating effects caused by gamma conversion and charged particles

- ✓ Conceptually, LENR neutrons act like catalytic matches that are used to 'light the logs' of target fuel nuclei. A neutron-catalyzed LENR transmutation network operates to release nuclear binding energy that has been stored and locked away in target fuel elements since they were originally produced in nucleosynthetic processes of long-dead stars, many billions of years ago
- ✓ LENR networks can produce usable process heat that arises mainly from:
  - Direct conversion of gamma photons (γ) into infrared photons (IR) by heavy electrons; e.g., γ from neutron captures or decays. IR is then scattered and absorbed by local matter, increasing its temperature
  - Nuclear decays in which energetic charged particles are emitted (e.g., alphas, betas, protons, deuterons, tritons); particles then transfer their kinetic energy by scattering on local matter, increasing its temperature
- ✓ Neutrino photons from weak interactions do not contribute to production of process heat; they essentially bleed-off a small portion of released nuclear binding energy into space; unavoidable neutrino emissions are part of the 'cost' of obtaining energy releases in LENR networks from $beta^-$ decays

Lattice Energy LLC

Overview of Widom-Larsen theory of LENRs

Much greener nuclear processes compared to fission and fusion

Here is why LENRs do not produce deadly fluxes of fast MeV-energy neutrons

- ✓ **Unlike energetic neutrons typically produced in nuclear reactions, collectively produced LENR neutrons are ~ standing still at the moment of creation in condensed matter. Since they are vastly below thermal energies (i.e., ultra low momentum), ULM neutrons have huge Q-M DeBroglie wavelengths and commensurately large capture cross-sections on nearby nuclei; virtually all will be captured locally --- only rarely will a tiny subset be externally detectable as minute emissions of free neutrons**

- ✓ **For vast majority of stable and unstable isotopes, effective neutron capture cross-sections (relative to measured cross-sections at thermal energies where v = 2,200 m/sec and DeBroglie wavelength is ~ 2 Angstroms) are directly related to ~1/v, where v is neutron velocity in m/sec. Since v in m/sec is negligible for ULM neutrons, their 1/v capture cross-sections on nuclei will be proportionately larger. After being created via *aikido* physics, vast majority of ULMNs will be captured locally before scattering on lattice atoms can elevate them to thermal kinetic energies**

Lattice Energy LLC

Overview of Widom-Larsen theory of LENRs

Much greener nuclear processes compared to fission and fusion

Here is why LENRs do not produce any deadly fluxes of MeV gamma radiation

- ✓ **Dynamic process whereby unreacted heavy-mass SP electrons in LENR-active patches can actively absorb and directly convert locally emitted or incident gamma radiation into many more less-energetic infrared (IR) photons at high efficiency while, of course, obeying the law of conservation of energy (has tiny, variable emission tail in soft X-rays)**

- ✓ **When ULM neutron captures onto an atom located inside entangled 3-D Q-M domain of an LENR-active patch, there are normally prompt gamma photon emissions by the atom. Since this capture-related gamma radiation occurs INSIDE the 3-D quantum mechanical structure of a 3-D LENR-active patch, there are always heavy electrons available nearby to absorb and convert such gamma emissions into IR. It doesn't matter *where* a gamma occurs inside a patch, it will always get converted; ditto for gammas associated with β-decays of local LENR transmutation products. Large fluxes of MeV gammas will not be emitted externally from such patches, no matter what x-y-z direction it is measured from**

Overview of Widom-Larsen theory of LENRs

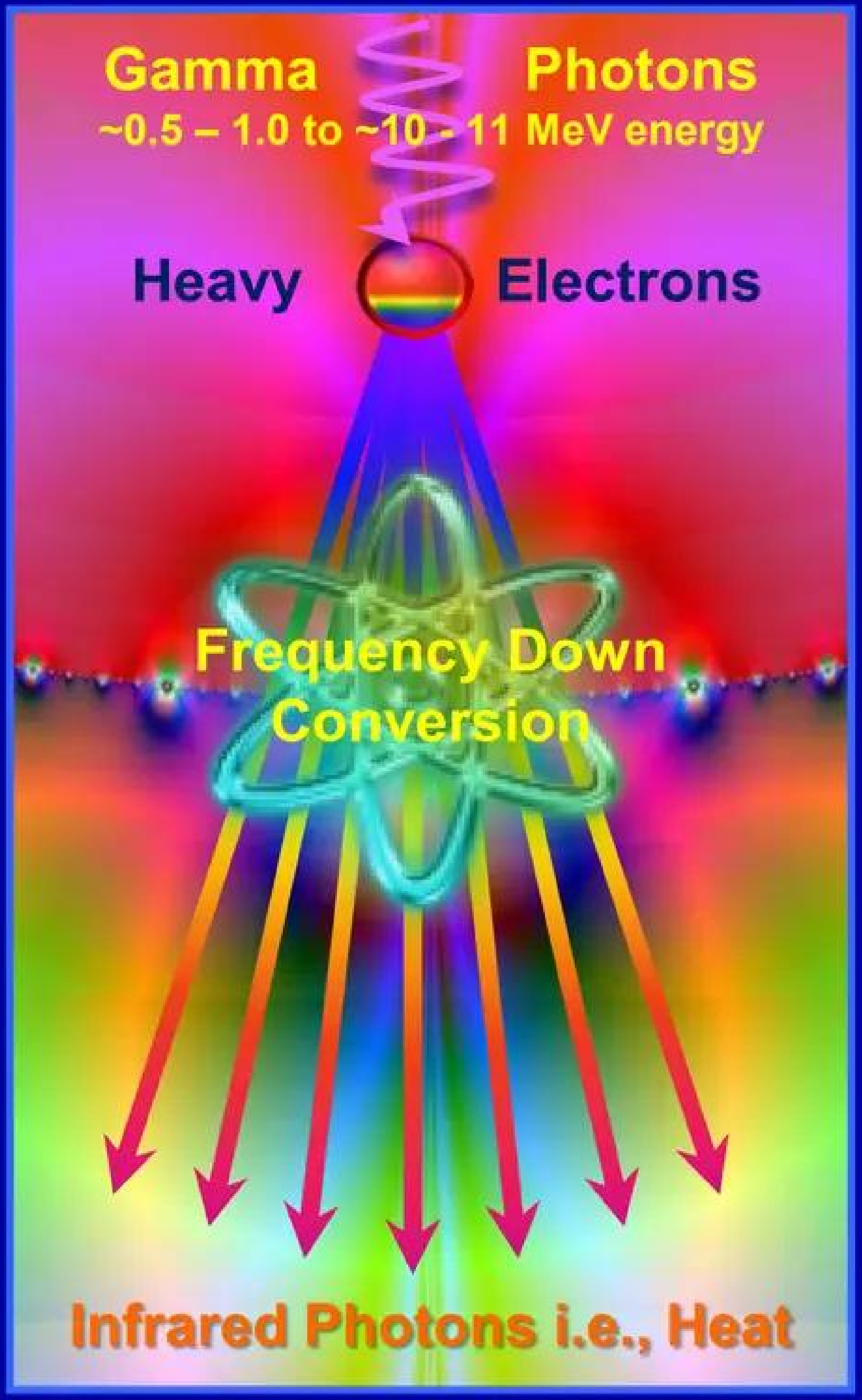
Fundamental patent covers LENRs in condensed matter devices

Issued patent: http://www.slideshare.net/lewisglarsen/us-patent-7893414-b2

US #7,893,414 B2

"Apparatus and Method for Absorption of Incident Gamma Radiation and its Conversion to Outgoing Radiation at Less Penetrating, Lower Energies and Frequencies"

Inventors: Lewis Larsen, Allan Widom
Issued: February 22, 2011
Assignee: Lattice Energy LLC



Abstract: "Gamma radiation (22) is shielded by producing a region of heavy electrons (4) and receiving incident gamma radiation in such region. The heavy electrons absorb energy from the gamma radiation and re-radiate it as photons (38, 40) at a lower energy and frequency. The heavy electrons may be produced in surface plasmon polaritons. Multiple regions (6) of collectively oscillating protons or deuterons with associated heavy electrons may be provided. Nanoparticles of a target material on a metallic surface capable of supporting surface plasmons may be provided. The region of heavy electrons is associated with that metallic surface. The method induces a breakdown in a Born-Oppenheimer approximation. Apparatus and method are described."

Overview of Widom-Larsen theory of LENRs

Very neutron-rich intermediates rapidly decay into stable isotopes

Here is why LENRs do not produce significant amounts of radioactive wastes

Examples explain how and why LENR transmutation networks have a very strong tendency to rapidly produce stable isotopes

- ✓ According to Widom-Larsen theory of LENRs, over time large fluxes of ULM neutrons will inevitably produce a build-up of relatively large populations of unstable, very neutron-rich isotopes
- ✓ At some point, all such neutron-rich isotopes will necessarily decay, mainly by series of rapid beta β^- cascades
- ✓ β^- decays release energetic β particles (electrons) that transfer kinetic energy to local matter, heating it up quickly
- ✓ Depending on half-lives, β^- chains can rapidly traverse entire rows of the periodic table, terminating in production of stable isotopes of heavier higher-Z elements. Long-running experiments with large ULMN fluxes produce many different stable isotopes and elements

Beta decay cascade

Palladium

$_{46}$Pd-117 HL = 4.3 sec
β- Q_v = 5.7 MeV
$_{47}$Ag-117 HL = 73 sec
β- Q_v = 4.2 MeV
$_{48}$Cd-117 HL = 2.5 hrs
β- Q_v = 2.5 MeV
$_{49}$In-117 HL = 43 min
β- Q_v = 1.5 MeV
$_{50}$Sn-117 Stable

Total Q_v = 13.9 MeV
Sum of HLs = 3.2 hrs

Silver

$_{47}$Ag-121 HL = 4.3 sec
β- Q_v =6.4 MeV
$_{48}$Cd-121 HL = 73 sec
β- Q_v = 4.9 MeV
$_{49}$In-121 HL = 2.5 hrs
β- Q_v = 3.4 MeV
$_{50}$Sn-121 HL = 27 hrs
β- Q_v = .39 MeV
$_{51}$Sb-121 Stable

Total Q_v = 15.1 MeV
Sum of HLs = 29.5 hrs

Nickel

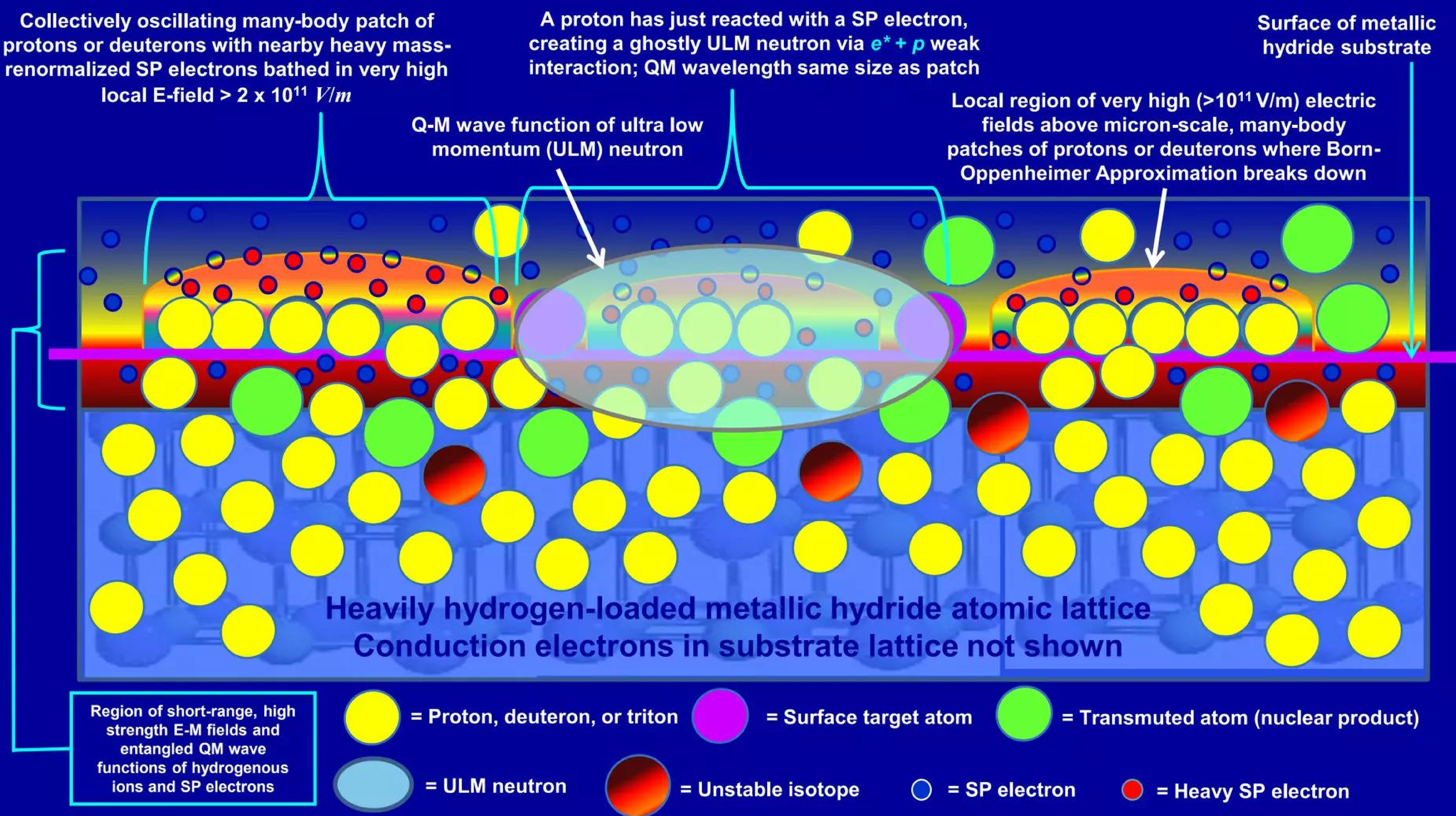
$_{28}$Ni-68 HL = 19 sec
β- Q_v = 2.1 MeV
$_{29}$Cu-68 HL = 31 sec
β- Q_v = 4.5 MeV
$_{30}$Zn-68 Stable

Total Q_v = 6.6 MeV
Sum of HLs = 50 sec

Using Deuterium as a base fuel, it costs a total of 7 ULM neutrons to make Pd-117 from Pd-110 at 0.39 MeV/neutron (total of 2.73 MeV) – the cascade releases 13.9 MeV, a net gain of ~11.2 MeV. It costs 12 ULMNs and 4.7 MeV to make Ag-121 from Ag-109; cascade releases 15.1 MeV, etc.

Overview of Widom-Larsen theory of LENRs

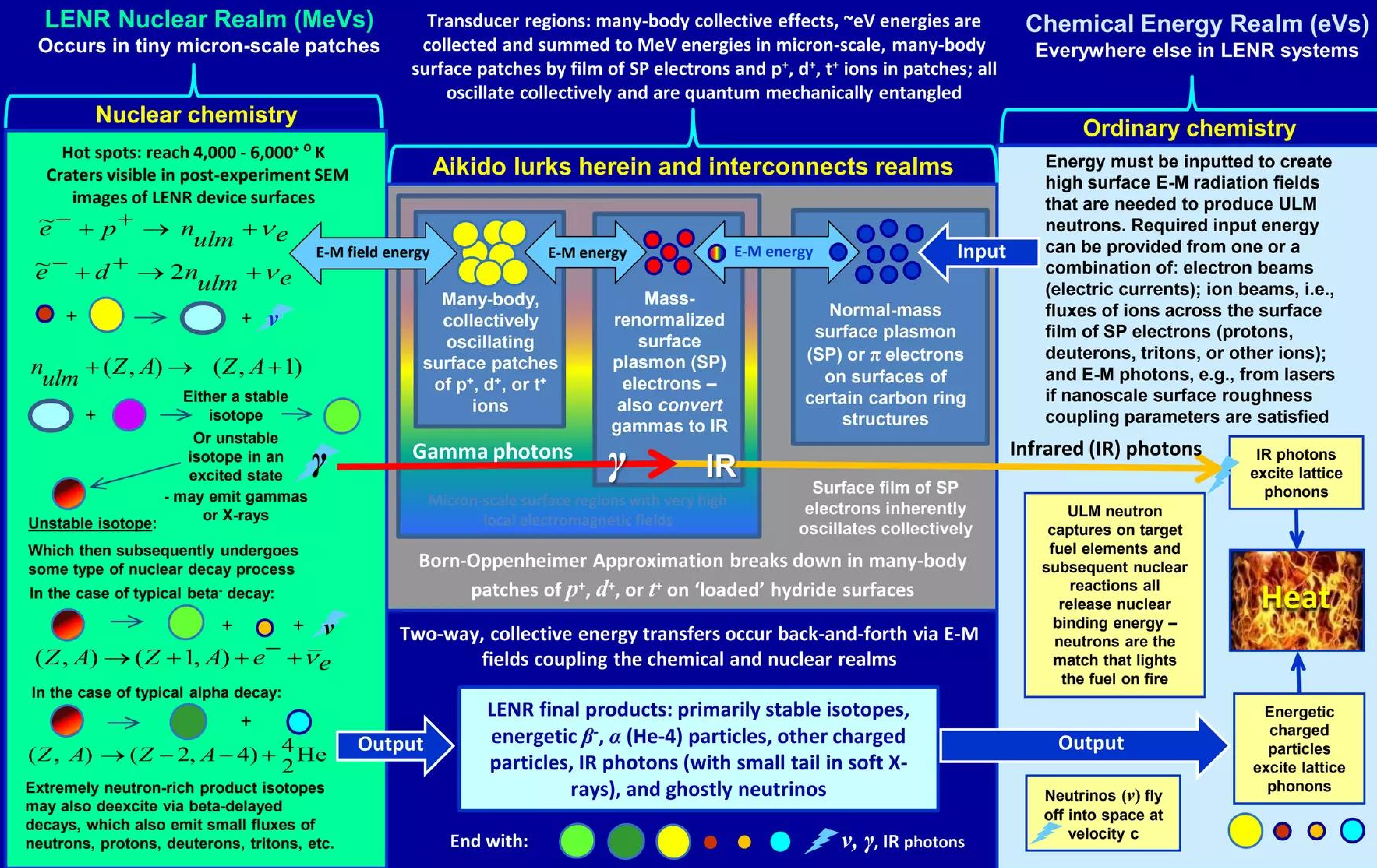
Shows key details of W-L mechanism operating in condensed matter



Lattice Energy LLC

Overview of Widom-Larsen theory of LENRs

Shows key details of W-L mechanism operating in condensed matter

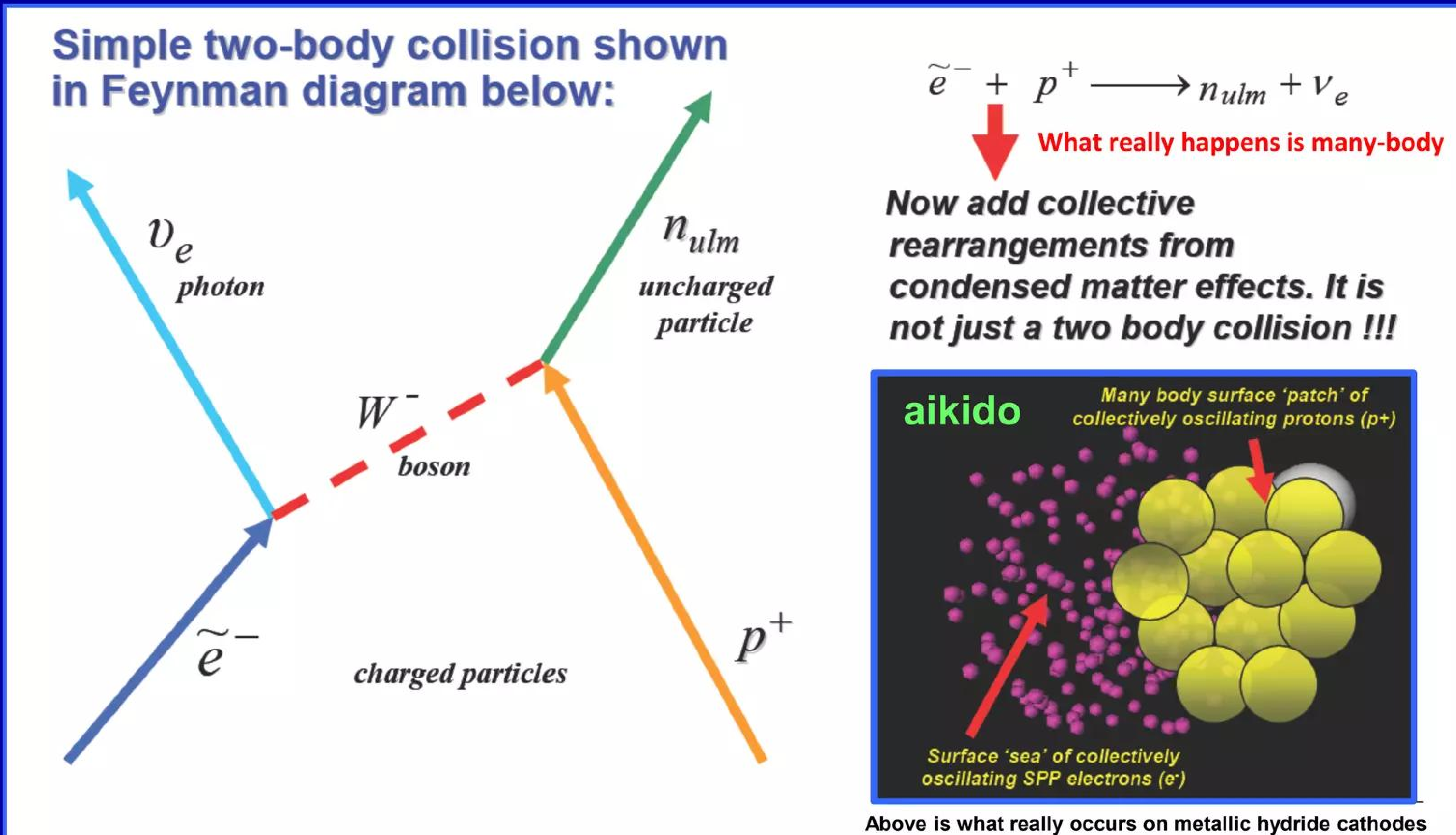


Lattice Energy LLC

Overview of Widom-Larsen theory of LENRs

Feynman diagram shows *e* + *p* reaction as simple two-body process

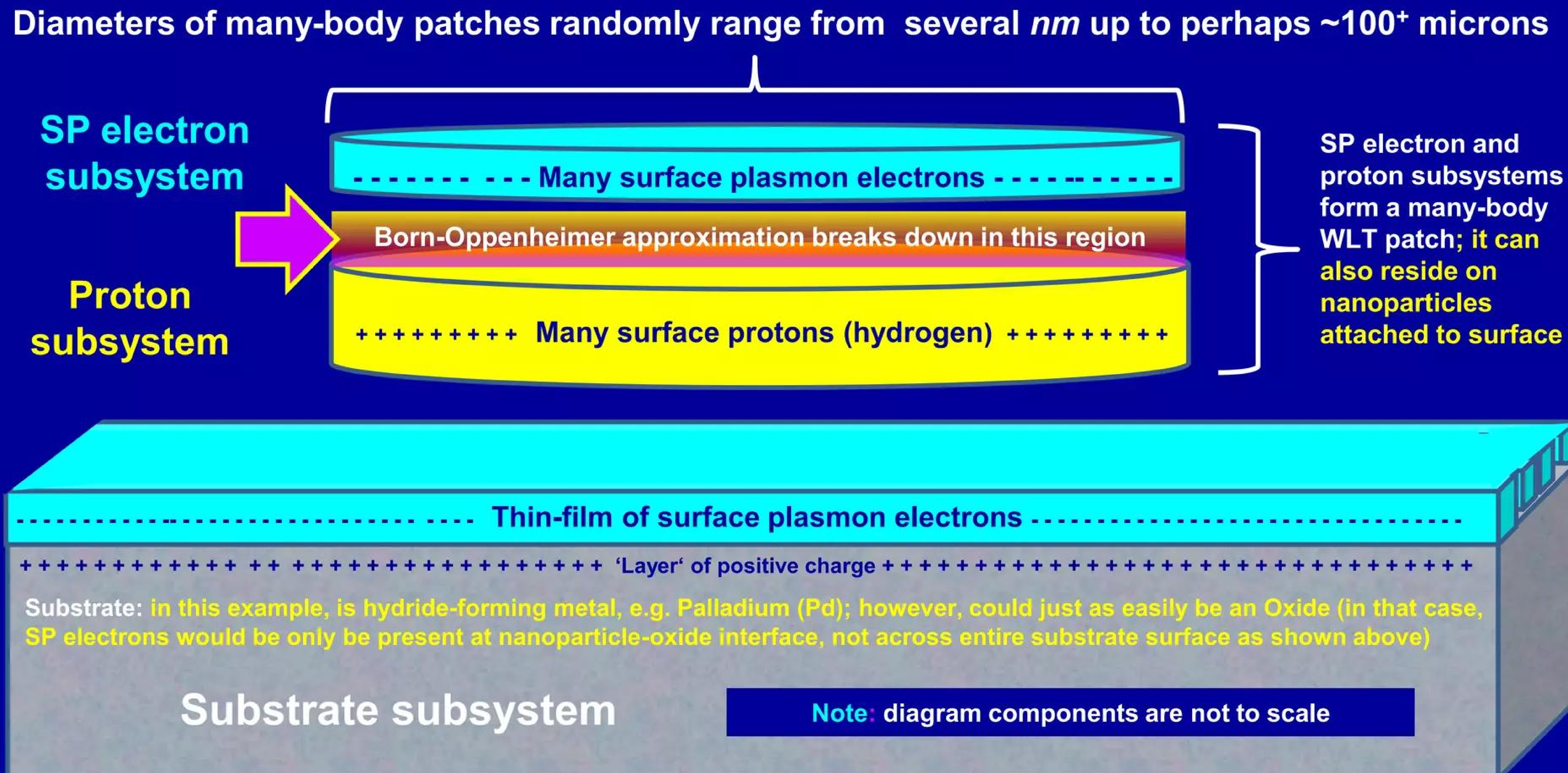
In lab and natural LENR systems *e* + *p* is really a many-body collective process



Overview of Widom-Larsen theory of LENRs

Conceptual overview of many-body patches that form on surfaces

SP electrons and protons oscillate collectively and are mutually Q-M entangled



Lattice Energy LLC

Overview of Widom-Larsen theory of LENRs

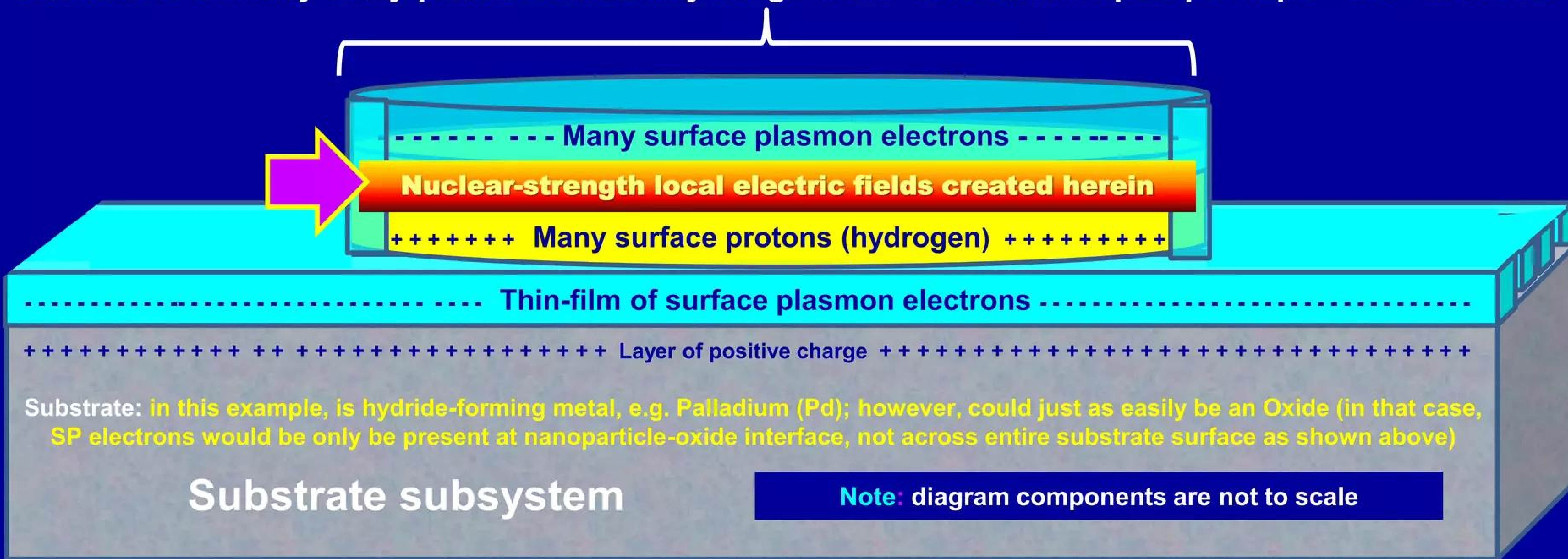
Born-Oppenheimer breakdown enables nuclear-strength e-fields

High local electric fields increase effective masses of some patch SP electrons

Sufficient input energy will create local E-fields > 10^{11} V/m within a patch which permits:

Input energy$_{\text{E-field}}$ + $e^{-}_{sp} \rightarrow e^{-*}_{sp} + p^{+} \rightarrow n + \nu_e$ [condensed matter surfaces]

Diameters of many-body patches randomly range from several *nm* up to perhaps ~100⁺ microns



Lattice Energy LLC

Overview of Widom-Larsen theory of LENRs

Collectively oscillating patches of protons form spontaneously

Wide range of diameters scattered randomly across surfaces where they form

Intense heating in LENR-active sites will form μ-scale event craters on substrate surfaces

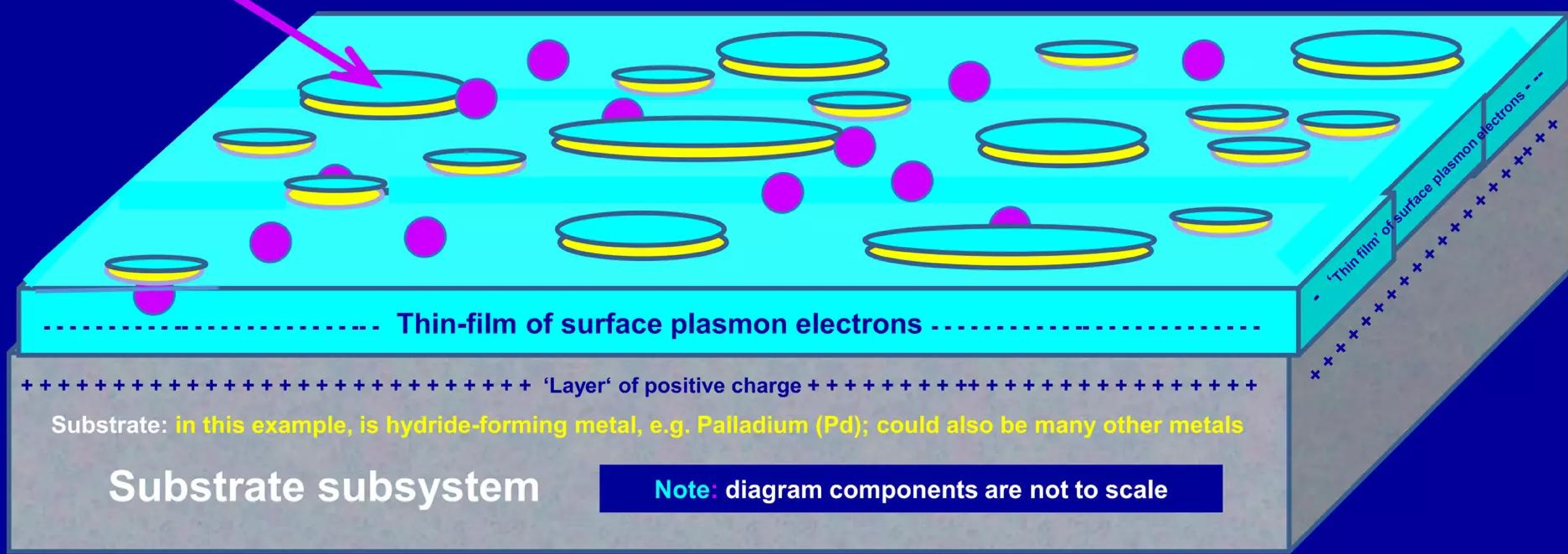
After being produced, neutrons will capture on targets in/around patches:

$n + (Z, A) \rightarrow (Z, A+1)$ [neutron capture on targets]

$(Z, A+1) \rightarrow (Z + 1, A+1) + e_{\beta}^{-} + \nu_e$ [beta$^-$ decay]

= Surface target atom

Often followed by β^- decays of neutron-rich intermediate isotopic products



Overview of Widom-Larsen theory of LENRs

Micron-scale LENR-active surface sites are dynamic entities

Sites only live for several hundred *ns* before intense heating destroys them

- ✓ LENR-active surface sites in condensed matter are not permanent entities or static structures; in fact, they are extraordinarily dynamic, short lived, many-body collective organizations of matter. In experimental or certain natural systems with sufficient input energy, when conditions are just right they will form spontaneously, operate for as little as 10 *ns* up to perhaps several hundred nanoseconds, and then suddenly die (they effectively destroy themselves with heat)

- ✓ Over time or the course of a given experiment, many cycles of birth, nuclear binding energy release, and death may be repeated over and over again at many different, randomly scattered *nm*-to *μm*-sized locations found on an LENR-active surface or interface; neutron-dose histories can vary greatly over small length-scales across an entire LENR-active surface. Such spatial elemental/isotopic heterogeneity has often been observed by LENR researchers with SIMS

- ✓ While ULM neutron production and local capture, gamma conversion to IR by heavy electrons, and subsequent nuclear decays are occurring, these tiny patches temporarily become hot spots. Their temperatures may briefly reach 4,000 - 6,000° K or perhaps even higher. That value is roughly as high as the surface temperature of the Sun and hot enough to melt and/or even flash-boil essentially all metals and alloys, including Tungsten (b.p. 5,666° C). For a brief time, a tiny dense ball of very hot, nanodusty plasma is created. Such intense local heating events can produce various types of distinctive explosive melting features and/or comparatively deep craters that are often observed in post-experiment SEM images of LENR device surfaces

Lattice Energy LLC

Overview of Widom-Larsen theory of LENRs

U.S. Navy SEM images of LENR-active surfaces show μ-scale craters

Fig. 6 from Karnakis *et al.* (2009)

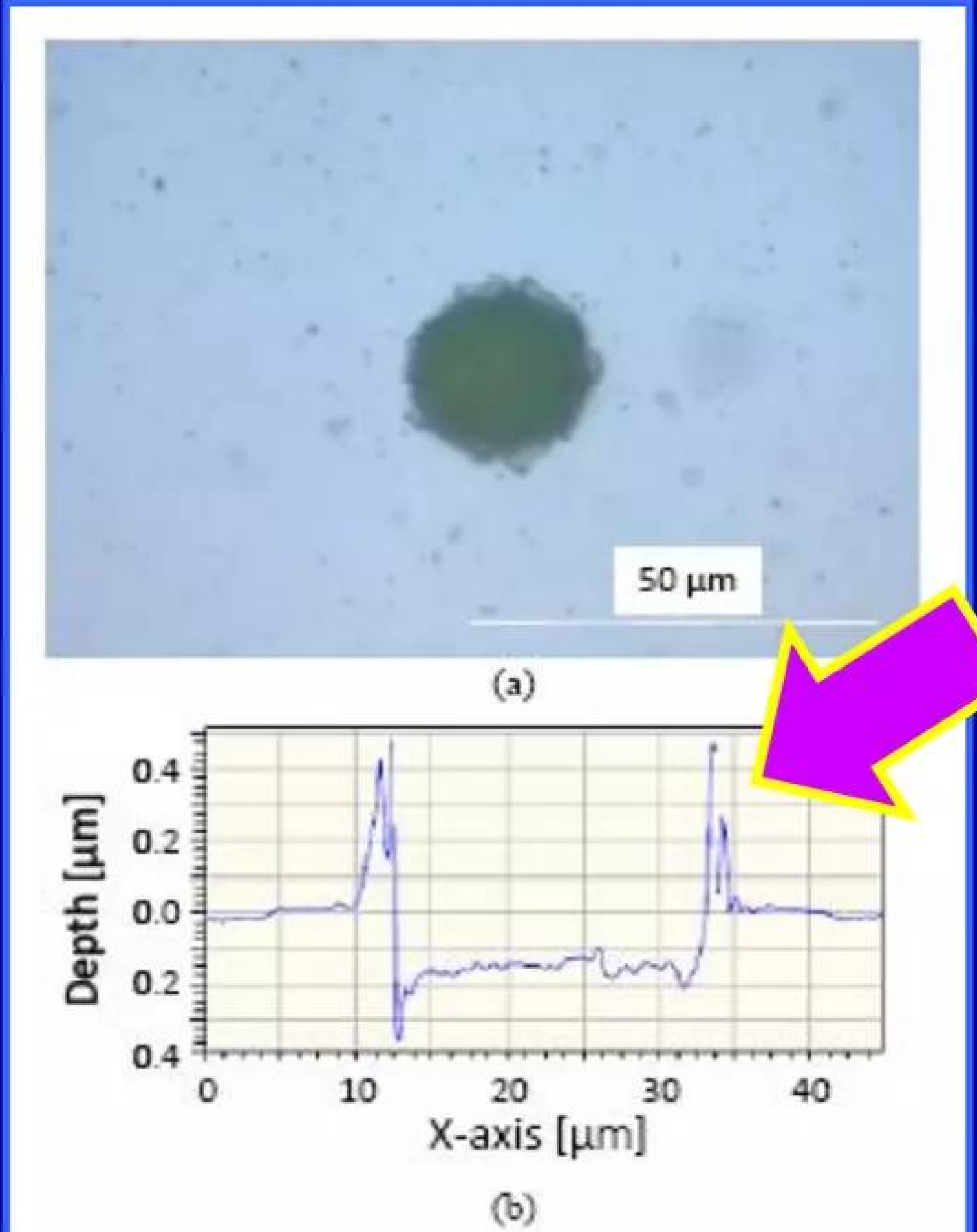


Fig. 6 (a) Optical microscope image of ps laser ablated cathode crater on LEP. Single pulse ablation, 532nm, 10ps, 2.5µJ; Bar 50µm, (b) Depth profile of the ablated crater, depth~140nm. Scale (X):2.5µm/div, (Y):25nm/div.

Quoting from Karnakis *et al.*:

"Laser irradiation at fluences between 137-360 *m*J/cm^2 removed the cathode layer only, resulting in a uniform flat floor and an intact LEP surface, allowing a relatively wide process window for cathode removal.

A typical example of such laser patterned Ba/Al cathode layer on the OLED stack is shown in Figure 6.

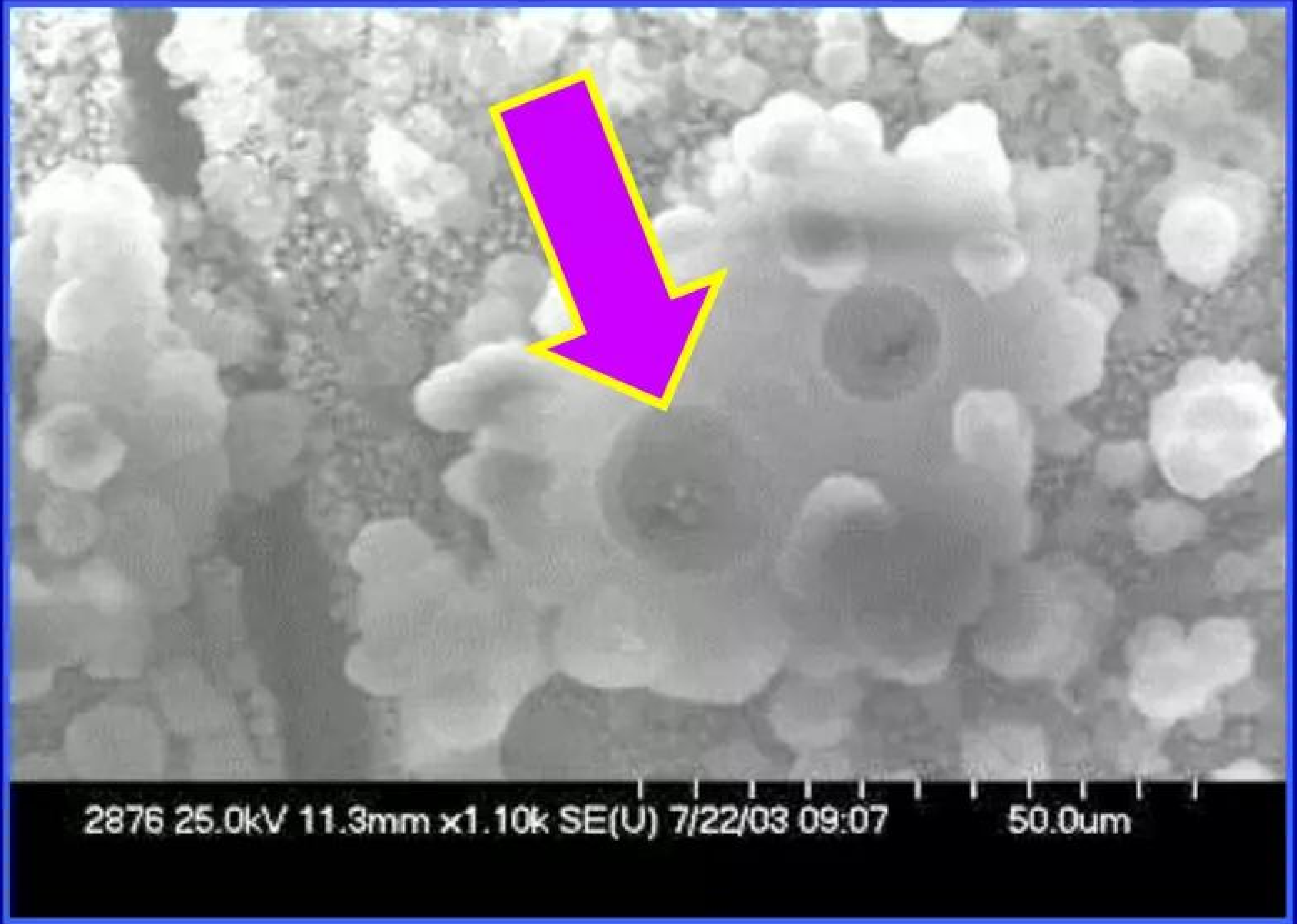
The average fluence was 230 mJ/cm^2 irradiated with an estimated spot diameter at 1/e^2 of 35 *µm*.

This resulted in a crater diameter of 21.5 *µm*."

Evidence for explosive boiling of metals:

Morphology of LENR craters is similar to ablative effects of energetic laser irradiation

Note microspheres formed at lips of craters



LENR Pd surface post-experiment: P. Boss *et al.*
U.S. Navy - SPAWAR

Excerpted and quoted directly from:

"Ultrafast laser patterning of OLEDs on flexible substrate for solid-state lighting"
D. Karnakis, A. Kearsley, and M. Knowles
***Journal of Laser Micro/Nanoengineering* 4 pp. 218 - 223 (2009)**
http://www.jlps.gr.jp/jlmn/upload/25e2c628adb23db70b26356271d20180.pdf

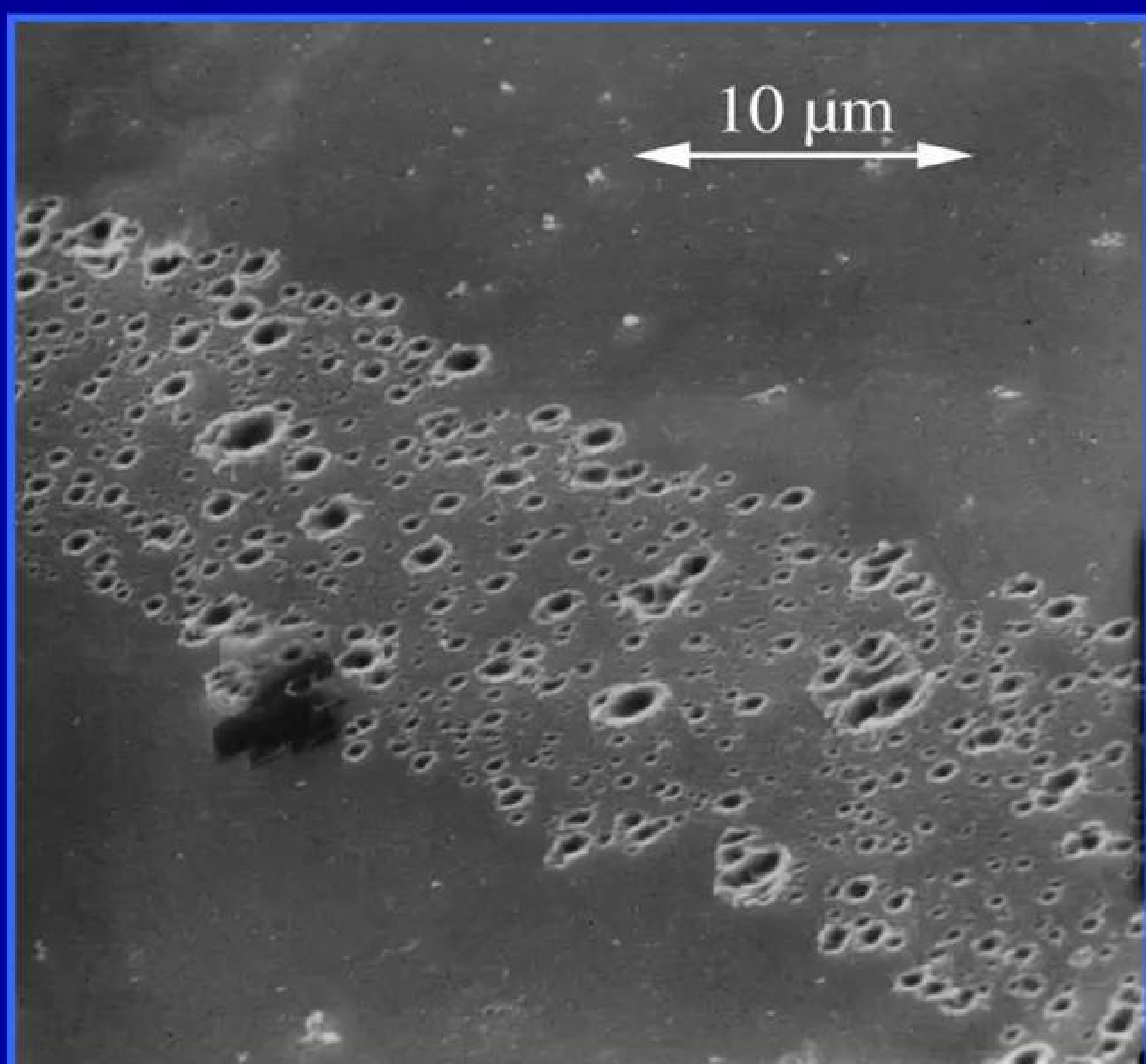
Overview of Widom-Larsen theory of LENRs

Zhang & Dash triggered LENR transmutations in electrolytic cells

Anders' SEM image vs. Zhang & Dash image of post-experiment LENR-active surface

Cathodic arc craters

A. Anders "Cathodic Arcs, and related phenomena" (2010)



A. Anders: Spot Type 1 - "contaminated" surface

LENR surface shown to right, which started-out smooth at the beginning of the experiment, appears to be much rougher in texture than the cathodic arc

Free copy of Zhang & Dash paper at:

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

Quoting from discussion of Fig. 10: "Ni was listed as "not detected" in the chemical analysis provided by the vendor of the Pd foil. It is very unlikely to have resulted from the cold rolling process or from electrodeposition because it is highly localized near one corner of the cathode. If it is the result of either contamination from the rolling mill or from electroplating it should not be highly localized on only one corner of the cathode. It could not have resulted from SEM systems because the stainless steel components of the SEM chamber also contain Fe and Cr. Fe and/or Cr are not present in any of the spectra. The SEM does not have components made of pure Ni. Therefore, the origin of the Ni is not known.".

LENR craters

Zhang & Dash (2007) --- Fig. 10. SEM picture of region #2 in Fig. 4(b). SEM No.WS060424Pd-H-CC-i2-150X

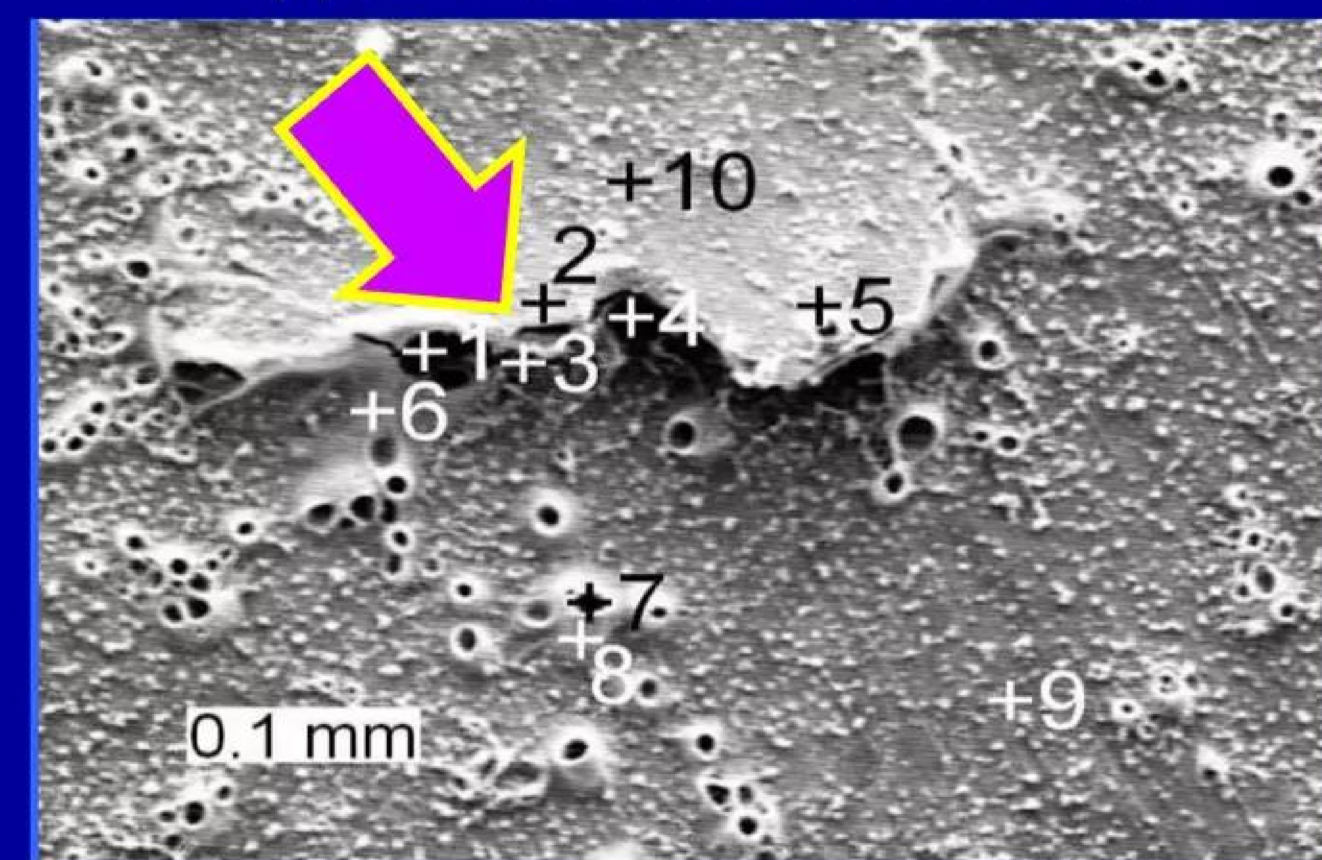
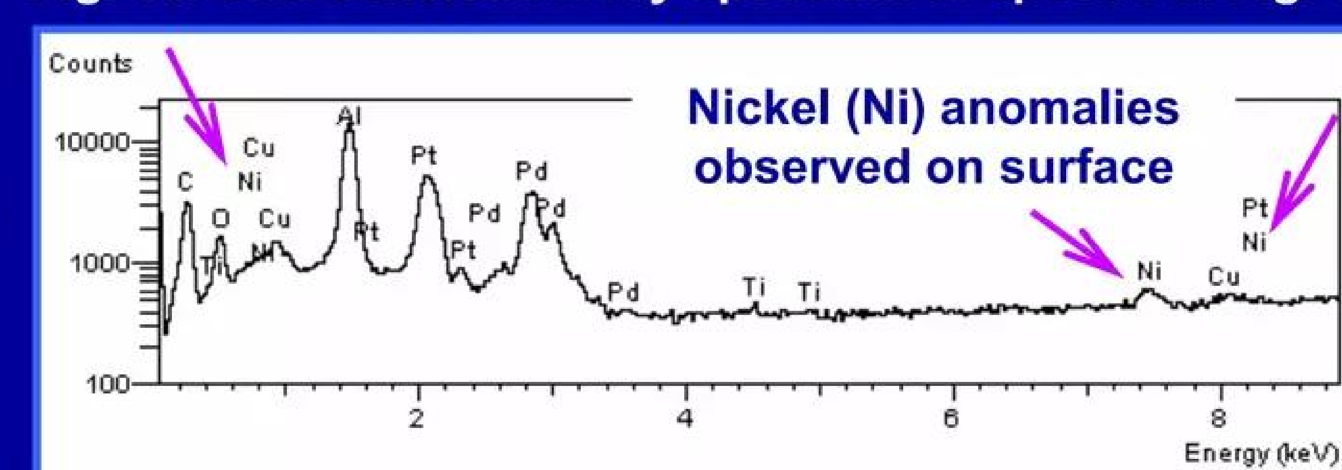


Fig. 11. Characteristic X-ray spectrum of spot #1 in Fig. 10.



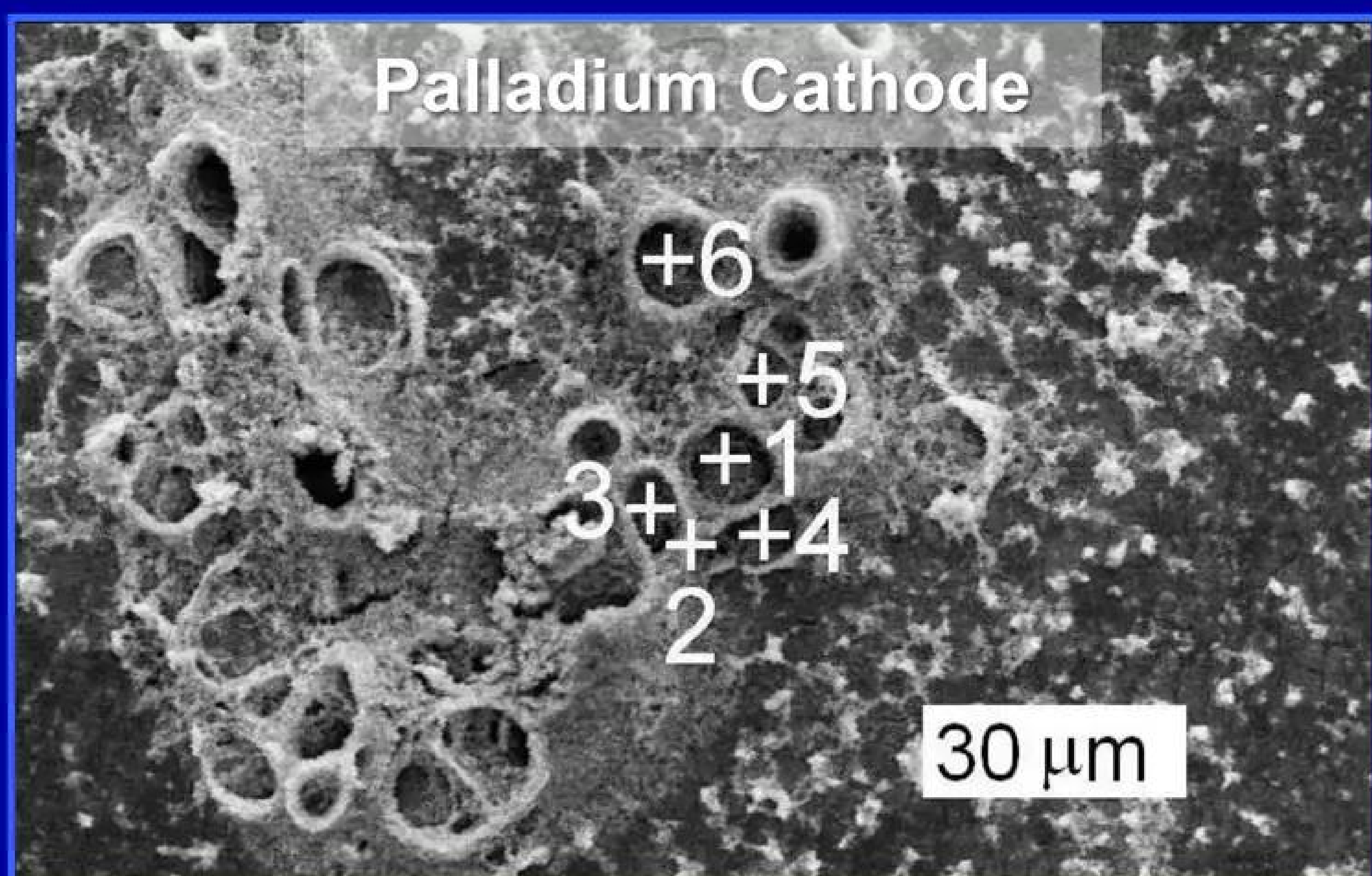
Lattice Energy LLC

Overview of Widom-Larsen theory of LENRs

Zhang & Dash triggered LENR transmutations in electrolytic cells

EDX analysis of post-LENR experiment surfaces showed anomalous Silver (Ag)

LENRs: Zhang & Dash (2007) - Fig. 8



Note: Pd surface b.p. = 2,970° C

LENRs: Zhang & Dash (2007) - Fig. 9

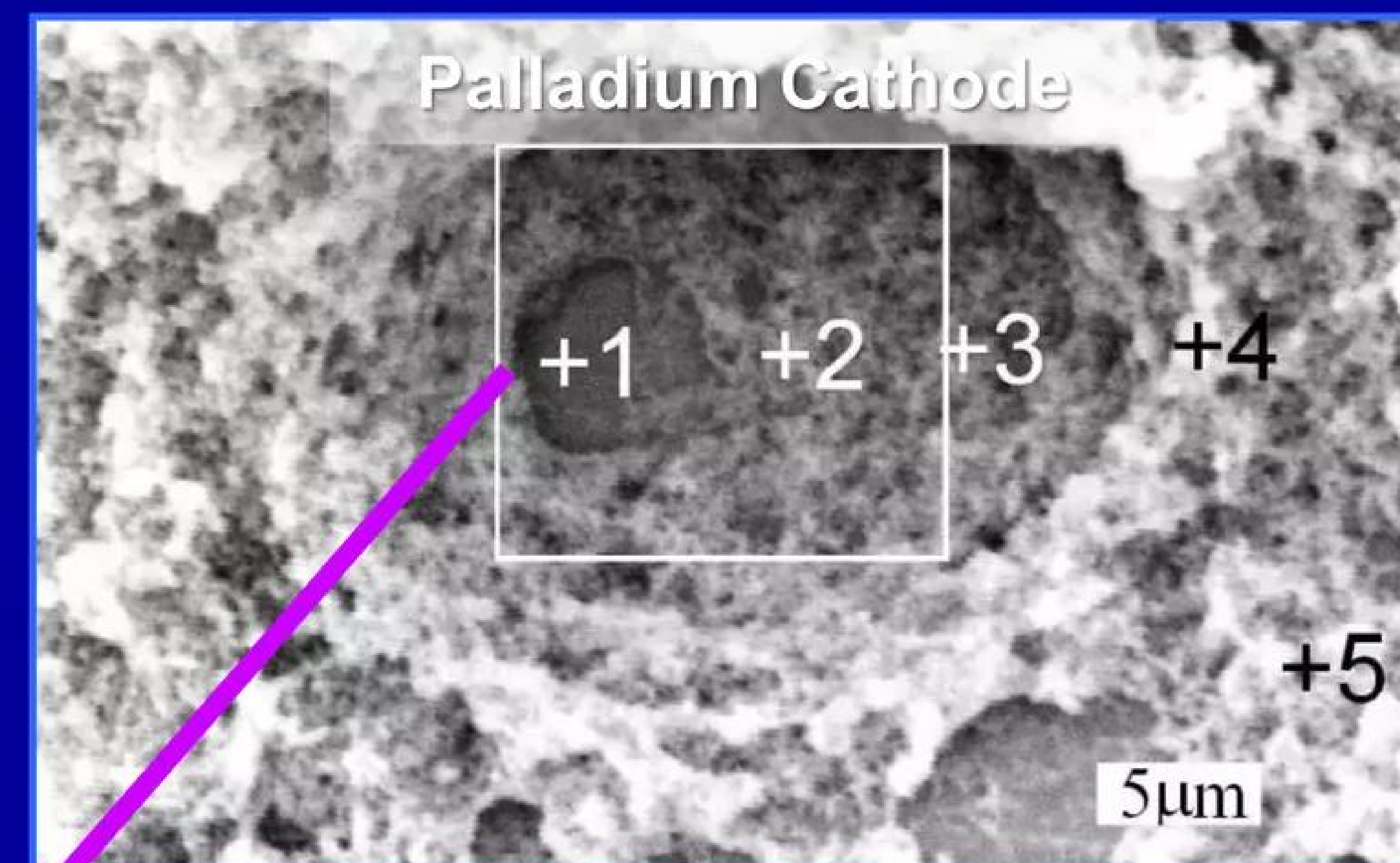


Fig. 9. SEM picture of crater at another time. SEM No.WS060607Pd-H-CC-i2-2kX

Free copy of Zhang & Dash paper at:

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

Quoting: "The most common finding is that silver occurs in craters, such as those shown in Fig. 8. These craters with rims almost certainly formed during electrolysis. Pt deposition was concentrated on these protruding rims."

Zhang and Dash: Table IX. Relative atomic percent concentrations of silver (Ag) in area and spots shown in Fig. 9

Spot #	wa*	area**	+1	+2	+3	+4	+5
Ag/(Pd+Ag)	1.2 +/- 0.5	5.6 +/- 0.4	6.8 +/- 0.4	5.6 +/- 0.3	6.3 +/- 0.4	3.6 +/- 0.6	1.2 +/- 0.5

*wa = whole entire area comprising image in Fig. 9

** area = delimited by the white square outlined in Fig. 9

Following likely took place in these experiments:

neutron capture — beta decay

Pd + *n* → unstable *n*-rich Pd isotope → Ag isotopes

Overview of Widom-Larsen theory of LENRs

Processes on LENR-active surfaces: complex, fast, and time-varying

Chemical and nuclear reactions occur simultaneously in parallel on same surface

- ✓ LENR hot spots create intense local heating and variety of readily noticeable surface features such as craters: over time, LENR-active surfaces inevitably experience major micron-scale changes in local nanostructures and elemental/isotopic compositions. On LENR-active substrate surfaces, there are a myriad of different complex, nanometer-to micron-scale electromagnetic, chemical, and nuclear processes that operate in conjunction with and simultaneously with each other. LENRs involve interactions between surface plasmon electrons, E-M fields, and many different types of nanostructures with varied geometries, surface locations relative to each other, different-strength local E-M fields, and varied chemical/isotopic compositions; chemical and nuclear realms interoperate

- ✓ To varying degrees, many of these complex, time-varying surface interactions are electromagnetically coupled on many different physical length-scales: thus, mutual E-M resonances can be very important in such systems. In addition to optical frequencies, SP and π electrons in condensed matter often also have some absorption and emission bands in infrared (IR) and UV portions of E-M spectrum. Well, walls of gas-phase metallic or glass LENR reaction vessels can emit various wavelengths of E-M photon energy into the interior space; glass tubes with inside surfaces coated with complex phosphors can function as resonant E-M cavities. Target nanostructures, nanoparticles, and/or molecules located inside such cavities can absorb IR, UV, or visible photons radiated from vessel walls if their absorption bands happen (or are engineered) to fall into same spectral range as E-M cavity wall radiation emission; complex two-way E-M interactions between targets and walls occurs (imagine interior of a reaction vessel as arrays of E-M nanoantennas with walls and targets having two-way send/receive channels)

- ✓ Wide variety of complex, interrelated E-M, nuclear, and chemical processes may be occurring simultaneously, side-by-side in adjacent *nm* to *μ*-scale local regions on LENR-active surfaces: for example, some regions on a given surface may be absorbing E-M energy locally, while others nearby can be emitting energy (e.g., as energetic electrons, photons, other charged particles, etc.). At same time, energy can be transferred laterally from regions of resonant absorption or capture to other regions in which energy emission or consumption is taking place: e.g., photon or electron emission, and/or LENRs in which: [E-M field energy] + $e^- \rightarrow e^{-*} + p^+ \rightarrow n_{ulm} + \nu$

Overview of Widom-Larsen theory of LENRs

Hard radiation not emitted - how does one confirm transmutations?

Mass spectroscopy techniques are best tools for detecting reaction products

- ✓ By early to mid-1990s, some LENR researchers located at smattering of major universities and national laboratories in Japan, Russia, Italy, and the US were already doing competent before-and-after analyses of experimental LENR devices using various types of mass spectroscopy. Mainly at ICCF conferences, they reported reliable observations of many new elements not initially present at beginning of experiments and/or substantial isotopic shifts in stable isotopes of elements initially present that could not reasonably be explained by any external contamination and/or action of prosaic chemical isotopic fractionation processes
- ✓ Some of those LENR researchers subsequently began using SIMS to assay isotopes post-experiment and were occasionally able to spatially correlate elemental or isotopic anomalies with distinctive morphological features observed on post-experiment metallic device surfaces: unusual structures found at such locations often consisted of micron-scale crater-like microstructures and other odd morphologies indicative of locally explosive flash melting or metal-boiling events. Indeed, it was Prof. George Miley's (Dept. of Nuclear Engineering, Univ. of Illinois at Urban-Champaign) distinctive 5-peak Ni/H_2O transmutation product mass-spectrum published in 1996 (mostly SIMS and neutron activation analyses data) that convinced Larsen to begin looking seriously into LENRs as energy source in 1997

Overview of Widom-Larsen theory of LENRs

DeBroglie wave function dimensions of ULM neutrons very large

Neutron captures occur faster than decays: neutron-rich isotopes accumulate

- ✓ Note that all of the many atoms located within a 3-D region of space that encompasses a given ULM neutron's spatially extended DeBroglie wave function (whose dimensions can range from 2 nm to 100 microns) will compete with each other to capture such neutrons. ULM neutron capture is thus a decidedly many-body scattering process, not few-body scattering such as that which characterizes capture of neutrons at thermal energies in condensed matter in which the DeBroglie wave function of a thermal neutron is on the order of ~2 Angstroms. This explains why the vast majority of produced neutrons are captured locally and not commonly detected at any energy during the course of experiments; it also clearly explains why lethal MeV-energy neutron fluxes are characteristically not produced in condensed matter LENR systems

- ✓ Half-lives of the most neutron-rich, unstable beta-decaying isotopes are generally rather energetic and relatively short , often on the order of milliseconds (10^{-3} sec). For example, very neutron rich Nitrogen-23 is unstable to beta decay with a measured half-life of ~14.5 milliseconds and Q-value of ~23 MeV; see Slide #12 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewcarbon-seed-lenr-networkssept-3-2009 Even so, ULM neutron capture processes generally occur at much faster rates than the decay rate of many beta- or alpha-unstable isotopes in LENR systems. If local ULM neutron production rates in a given patch are high enough, this large difference in rates of beta decay versus neutron capture processes means that populations of unstable, neutron-rich isotopes can potentially accumulate locally during the typically brief lifetime of an LENR-active patch, prior to destroying itself

Overview of Widom-Larsen theory of LENRs

Experimental data suggests unstable neutron-rich intermediates

LENR transmutation networks can operate very fast but have short lifespans

- ✓ Please note that the Q-value for neutron capture on a given beta-unstable isotope can sometimes be larger than the Q-value for the alternative β- decay pathway, so in addition to being a faster process than beta decay it can also be energetically more favorable. This can help to create local populations of neutron-rich isotopes. There is indirect experimental evidence that such neutron-rich isotopes can be produced in complex ULM neutron-catalyzed LENR nucleosynthetic (transmutation) networks that set-up and operate during the lifetime of a patch; for example see the Carbon-seed network on Slides # 11 - 12 and especially on Slide #55 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewcarbon-seed-lenr-networkssept-3-2009 and a Tungsten-seed network segment on Slide # 60 in http://www.slideshare.net/lewisglarsen/cfakepathlattice-energy-llc-len-rs-in-liion-battery-firesjuly-16-2010

- ✓ Beginning with so-called seed or target starting nuclei upon which ULM neutron captures are initiated, complex, very dynamically changing LENR nucleosynthetic networks are established in LENR-active patches. These ULM neutron-catalyzed LENR networks exist for the lifetime of the particular patch in which they were created; except for any still-decaying transmutation products that may linger, such networks typically die along with the LENR-active patch that originally gave birth to them. Seed nuclei for such networks can comprise any atoms in a substrate underlying an LENR-active patch and/or include atoms located nearby in various types of surface nanoparticles or nanostructures that are electromagnetically connected to a patch

Overview of Widom-Larsen theory of LENRs

Transmutation reaction networks begin with target or seed elements

- ✓ For an example of a Carbon-seed LENR network please see Slides # 11 - 12 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewcarbon-seed-lenr-networkssept-3-2009 ; for a Potassium-seed LENR network see Slide # 57 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewjune-25-2009 for a Palladium-seed LENR network see Slides # 52 - 53 in http://www.slideshare.net/lewisglarsen/lattice-energy-llcnickelseed-lenr-networksapril-20-2011 for a Nickel-seed LENR network see Slides # 20 - 22 in http://www.slideshare.net/lewisglarsen/lattice-energy-llcnickel-seed-wl-lenr-nucleosynthetic-networkmarch-24-2011 ; and lastly for a Thorium-seed LENR network see Slides # 3 - 4 in http://www.slideshare.net/lewisglarsen/thoriumseed-lenr-networkfigslattice-energydec-7-2010-6177745

- ✓ Per Widom-Larsen, once ULM neutron production begins at high rates, populations of unstable, very neutron-rich so-called halo isotopes build-up locally in LENR-active patches found on ~2-D condensed matter surfaces. As explained in Slide #24 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewjune-25-2009 , such nuclei likely have somewhat retarded decays because they can have a difficult time emitting beta electrons, neutrons, or even neutrinos (all of which happen to be fermions) into locally unoccupied fermionic states. Consequently, such unstable halo nuclei may often continue capturing ULM neutrons until they finally get so neutron-rich, or a previously occupied state in the local continuum opens-up, that 'something breaks' and spontaneous beta decay cascades ending in stable isotopes are initiated

Lattice Energy LLC

Overview of Widom-Larsen theory of LENRs

Transmutation reaction networks are complex - release thermal energy

- ✓ Depending on half-lives of intermediate isotopes, β- decay chain cascades can very rapidly traverse rows of the periodic table; thus, long-running LENR experiments with large ULMN fluxes can produce a broad variety of different stable elements in surprisingly short periods of time. For example, in one unrepeatable yet nonetheless spectacular experiment, Mizuno (Hokkaido University, Japan) went from Potassium (K) to Iron (Fe) in less than 2 minutes; see Slides # 54 - 59 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewjune-25-2009 For examples of beta-decay cascades see Slide #19 in http://www.slideshare.net/lewisglarsen/lattice-energy-llcnickel-seed-wl-lenr-nucleosynthetic-networkmarch-24-2011

- ✓ LENR transmutation network pathways comprising series of picosecond neutron captures interspersed with serial beta-decay cascades can release substantial amounts of nuclear binding energy, much of it in the form of usable thermal process heat; e.g., there is a multi-step Carbon-seed LENR transmutation network pathway that can release ~386 MeV over an average period of ~3.4 hours. This total energy release is comparable to fission (U-235 is ~190 MeV) but without any high-energy neutron or gamma emission or production of long-lived radioactive isotopes; see Slide #55 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewcarbon-seed-lenr-networkssept-3-2009 When neutron-creating energy inputs cease, then decay processes begin to dominate in an LENR system; namely, serial cascades (chains) of fast beta decays from unstable neutron-rich intermediates all the way down to stable isotopes/elements. Importantly, few long-lived radioisotopes would remain after these rapid decay processes complete. This is precisely why LENR-active patches have a strong tendency to produce stable isotopes as end-products

Overview of Widom-Larsen theory of LENRs

Proprietary aspects of W-L provide guidance for device engineering

- ✓ Rates of LENRs can be increased substantially in non-natural environments: fortunately, using proprietary conceptual insights provided by W-L theory, experimental conditions in condensed matter systems and dusty plasmas can be technologically tweaked to greatly increase rates of weak reaction neutron production far above what are ever attainable in analogous systems found at random out in Nature or in the vast majority of LENR laboratory experiments conducted to date

- ✓ Technologically, many-body collective electroweak neutron production rates can be manipulated by: (1) controlling total numbers and density of $e^{-*}p^{+}$ pairs on a given surface (which is ~equivalent to controlling the area-density and dimensions of many-body, collectively oscillating surface patches of protons or deuterons); and (2) controlling the rate and total quantity of appropriate form(s) of nonequilibrium energy input into many-body LENR-active surface patches; appropriate forms of input energy can go directly into high electric fields that bathe SP electrons in a patch --- it determines the number and effective masses of e* electrons present in a given patch whose increased masses are at values somewhere above the minimum mass-renormalization threshold ratio, β_0 that is required for initiating $e^{-*} + p^{+}$ or $e^{-*} + d^{+}$ weak reactions

- ✓ Term $(\beta - \beta_0)^2$ in our published rate equation reflects the degree to which mass renormalized e^{-*} electrons in a given 'patch' exceed the minimum threshold ratio for neutron production β_0. Details of this are explained in our first principles ULM neutron production rates calculation paper found on the Cornell arXiv at: http://arxiv.org/PS_cache/nucl-th/pdf/0608/0608059v2.pdf

- ✓ All other things being equal, the higher the density of $e^{-*}p^{+}$ reactants and the greater the rate and quantity of appropriate forms of nonequilibrium energy inputs, the higher the rate of ULM neutron production in μm-scale LENR-active patches in correctly pre-configured condensed matter systems

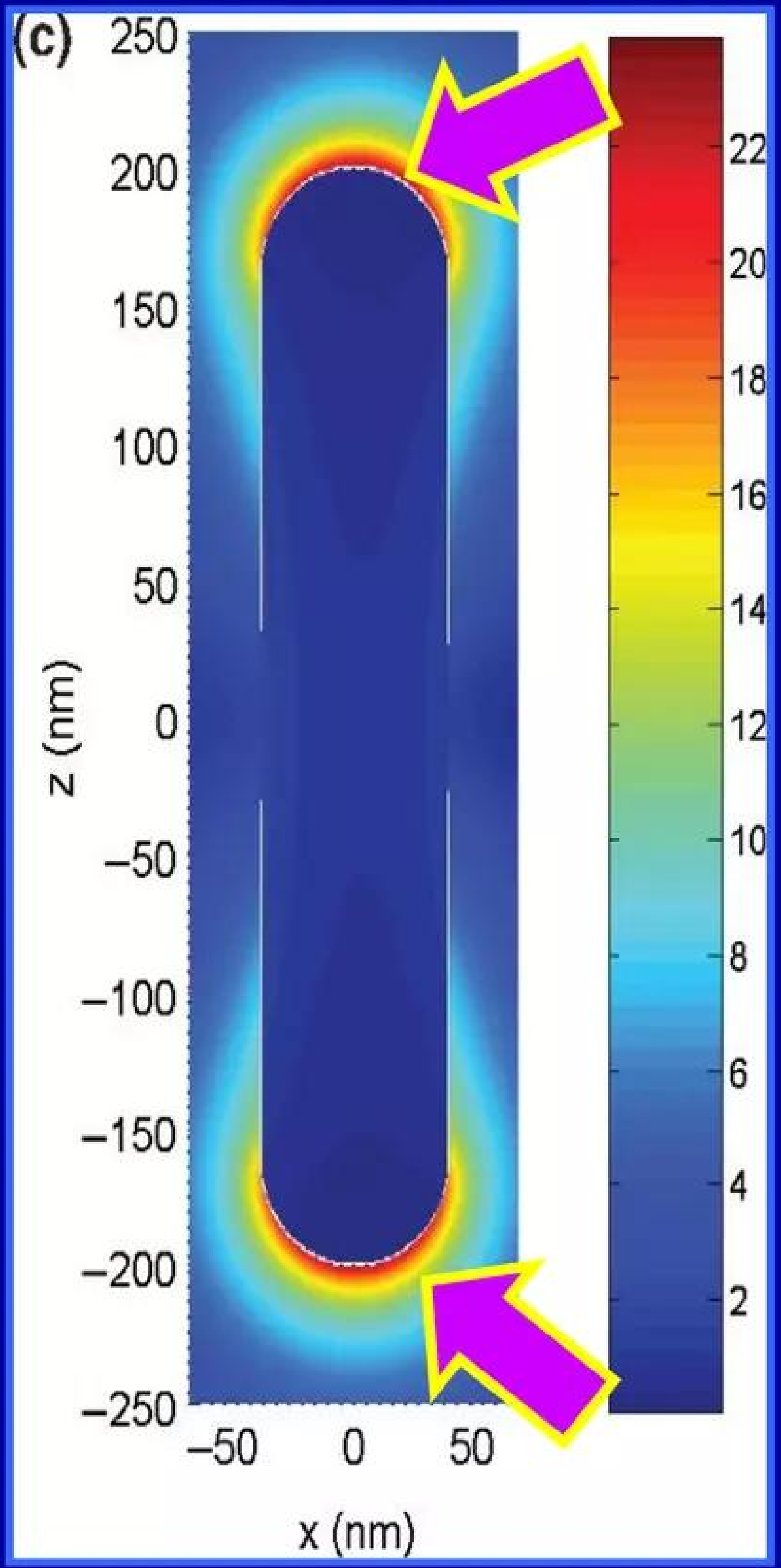
Overview of Widom-Larsen theory of LENRs

Commercialization of LENR devices requires nanotech and plasmonics

LENRs, plasmonics, and nanotechnology joined at the hip:

- ✓ Just like nanotech, LENRs inhabit the intersection of many different disciplines such as: chemistry; solid-state, surface, and nuclear physics; materials science; plasmonics; etc.
- ✓ Interdisciplinary condensed matter LENRs, plasmonics, and nanotechnology are effectively joined at the hip; collective, many body classical, and coherent quantum effects occur and are very crucial in all three of these 21st century technologies
- ✓ Various 'species' of nanotechnologists have the necessary knowledge and expertise to make important theoretical and experimental contributions to further expanding our present understanding of intensely multidisciplinary LENRs and the fascinating regions of parameter space in which they occur
- ✓ Lattice has been and is presently applying and utilizing nanotechnology in its effort to commercialize LENRs; for obvious reasons, such work is nonpublic and proprietary

Distribution of nearfield enhancement in Gold nanorod: L=400 nm and D=80 nm



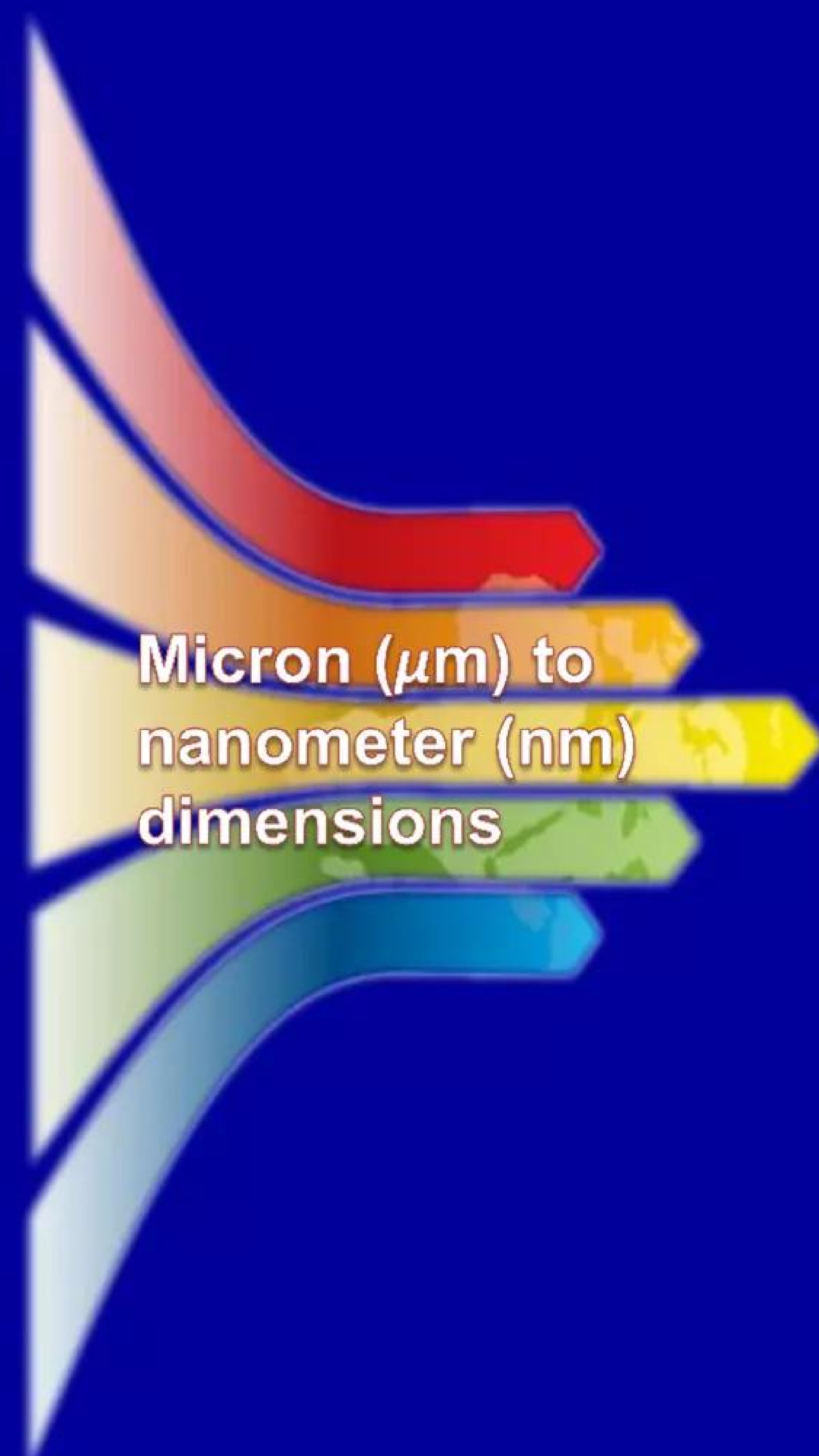
A. Pucci *et al.*, Chapter 8 in ISBN 978-0-387-74131-4 Springer New York, Fig. seen on pp. 182 (2008)

Overview of Widom-Larsen theory of LENRs

Science of LENRs is an incredibly multi-disciplinary field of study

Many-body collective effects on small length-scales enables the 'impossible'

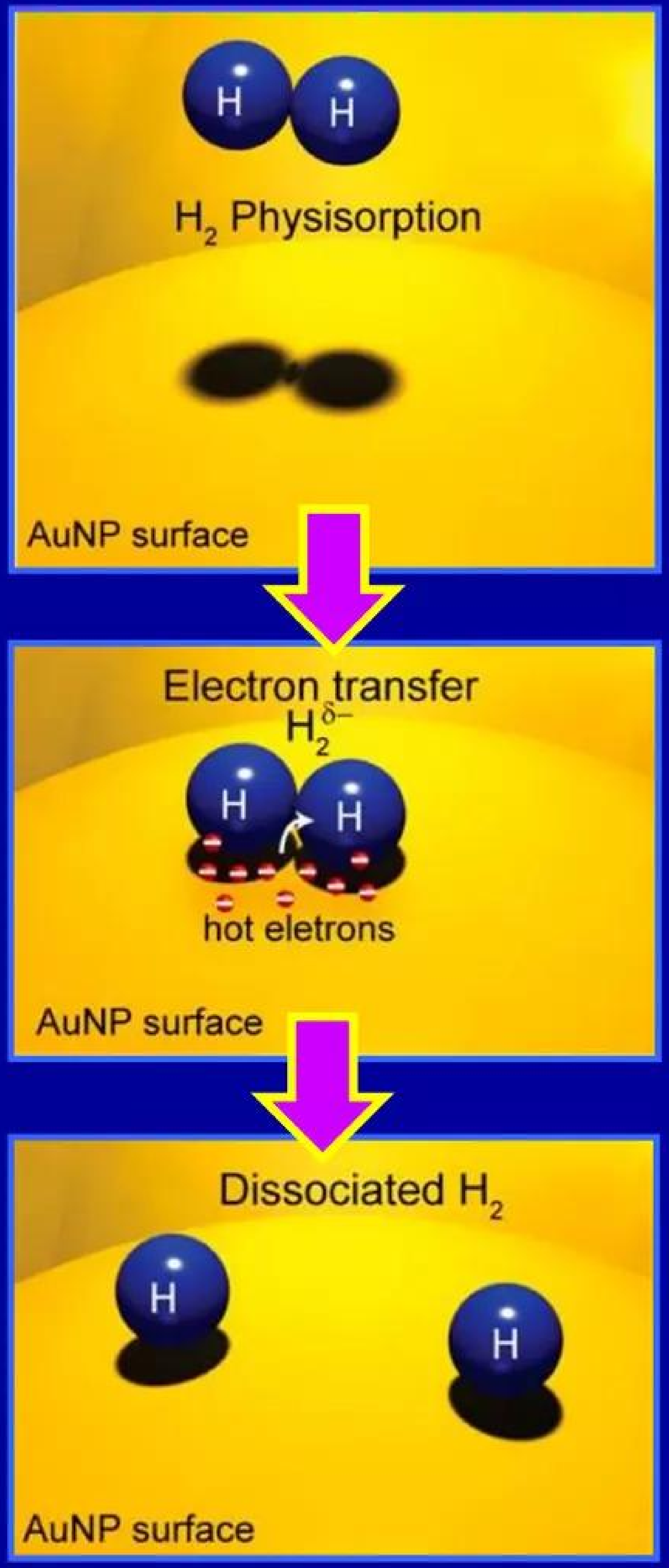
Quantum electrodynamics (QED)
Collective many-body effects
Modern quantum mechanics
Condensed matter physics
Classical electrodynamics
Modern nuclear physics
Surface chemistry (H)
All nanotechnology
Surface physics
Plasma physics
Plasmonics



Science and technology of low energy nuclear reactions (LENRs) in condensed matter systems utilizes knowledge from all of these varied disciplines

Overview of Widom-Larsen theory of LENRs

Example: first experimental evidence for room temp. dissociation of H_2



"Hot electrons do the impossible: plasmon-induced dissociation of H_2 on Au"
S. Mukherjee *et al.*
***NANO Letters* 13 pp. 240 - 247 (2013)**
http://pubs.acs.org/doi/pdf/10.1021/nl303940z

ABSTRACT: "Heterogeneous catalysis is of paramount importance in chemistry and energy applications. Catalysts that couple light energy into chemical reactions in a directed, orbital-specific manner would greatly reduce the energy input requirements of chemical transformations, revolutionizing catalysis-driven chemistry. Here we report the room temperature dissociation of H_2 on gold nanoparticles using visible light. Surface plasmons excited in the Au nanoparticle decay into hot electrons with energies between the vacuum level and the work function of the metal. In this transient state, hot electrons can transfer into a Feshbach resonance of an H_2 molecule adsorbed on the Au nanoparticle surface, triggering dissociation. We probe this process by detecting the formation of HD molecules from the dissociations of H_2 and D_2 and investigate the eﬀect of Au nanoparticle size and wavelength of incident light on the rate of HD formation. This work opens a new pathway for controlling chemical reactions on metallic catalysts."

Widom-Larsen theory explains MHI and Toyota data

Cesium

Praseodymium

Neutron captures and decays produced results

Widom-Larsen theory explains MHI and Toyota data

Lattice published its explanation for MHI's transmutation data in 2009

Lattice Energy LLC

Commercializing a Next-Generation Source of Safe Nuclear Energy

Low Energy Nuclear Reactions (LENRs)

Widom-Larsen theory, weak interactions, transmutations, nanoscale evidence for nuclear effects, and the road to commercialization

Mitsubishi's experimental results are explained on slides: #65 - 67 (Ba targets); #44 - 45 (Cs and Sr targets)

Technical Overview

Lewis Larsen, President and CEO

Explosive runaway event in electrolytic cell went from K → Fe in less than two minutes: see slides #56 - 59

"Energy, broadly defined, has become the most important geostrategic and geoeconomic challenge of our time."

Thomas Friedman
New York Times, April 28, 2006

June 25, 2009 Copyright 2009 Lattice Energy LLC All Rights Reserved 1

Source: http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewjune-25-2009

Lattice Energy LLC

Widom-Larsen theory explains MHI and Toyota data

Necessary energy inputs were provided by D_2 temperature/pressure

ULM neutron fluxes produced by MHI method <<< lower than electrolytic cells

- ✓ **Question:** using W-L theory of LENRs, are there plausible neutron-catalyzed nucleosynthetic pathways that have adequate Q-value energetics, half-lives, and neutron capture cross-sections that can explain the central results of Mitsubishi (2002) and Toyota's (2013) D_2 (Deuterium) permeation experiments in which ^{133}Cs (Cesium) was transmuted into ^{88}Sr (Strontium)?
- ✓ **Answer:** yes, theoretically possible pathways that fully explain these published experimental results are provided in diagrams shown on the next five slides
- ✓ **Note:** Widom-Larsen theory also successfully explains other Mitsubishi D_2 permeation experiments in which ^{88}Sr (Strontium) was transmuted into ^{96}Mo (Molybdenum) and experiments in which Barium (Ba) isotopes were transmuted into Samarium (Sm)

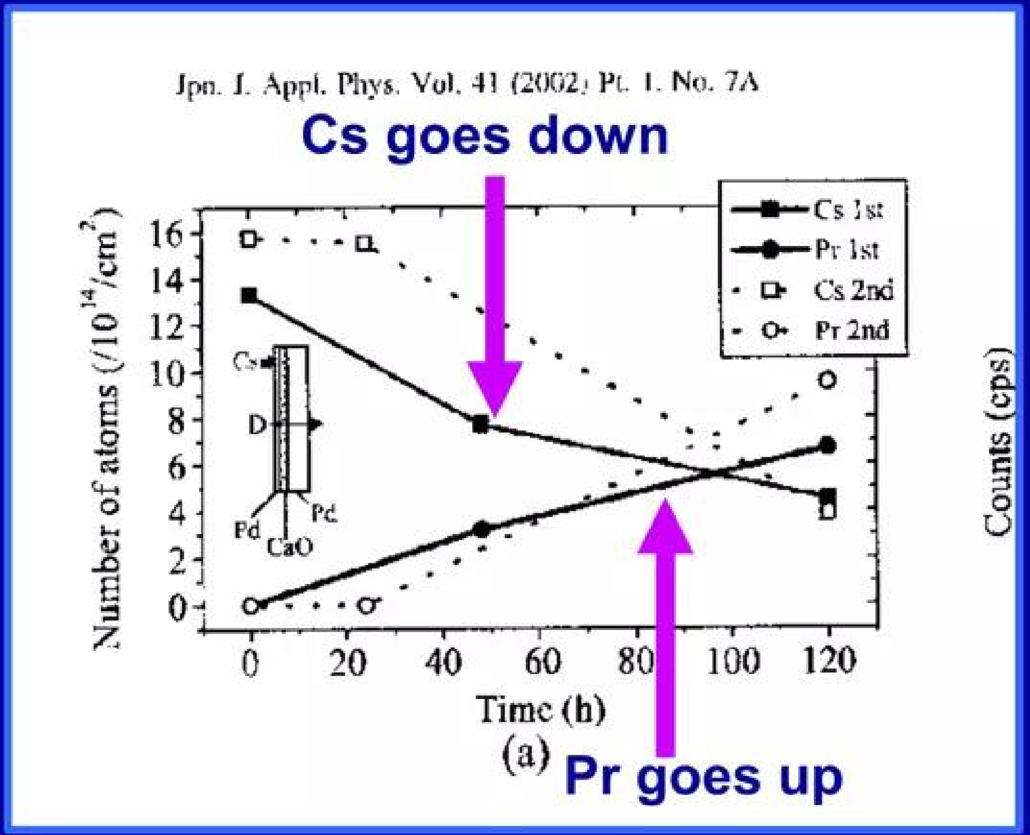
"Elemental analyses of Pd complexes: effects of D_2 gas permeation"
Y. Iwamura *et al.*
Japanese Journal of Applied Physics
41 pp. 4642 - 4650 (2002)

Central results were as follows:

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

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

Isotopes on samples' surfaces analyzed in roughly real- time during the course of the experiments using XPS technique



Widom-Larsen theory explains MHI and Toyota data

Neutron-catalyzed transmutation: Barium (Ba) → Samarium (Sm)

Comments on Mitsubishi's experimental results reported at ICCF-11 in 2006

- ✓ Used experimental set-up very similar to what was utilized in the work reported in 2002 *JJAP* paper and Toyota in 2013
- ✓ Natural abundance Ba as well as ^{137}Ba enriched targets were electrochemically deposited on the surfaces of thin-film Pd-complex device heterostructures
- ✓ Ba targets subjected to a D^+ ion flux for 2 weeks; flux was created by forcing D_2 gas to permeate (diffuse) through the thin-film structure via a pressure gradient imposed between the target side and a mild vacuum on the other
- ✓ Central results of these LENR experiments were the observations of Ba isotopes being transmuted to Samarium isotopes $_{62}Sm^{149}$ and $_{62}Sm^{150}$ over a period of two weeks (see documents cited to the right for experimental details)
- ✓ XPS and SIMS were used to detect elements and isotopes
- ✓ Among other things, they concluded that, " … a very thin surface region up to 100 angstrom seemed to be active transmutation zone," which is consistent with W-L theory

Reference:

"Observation of nuclear transmutation reactions induced by D_2 gas permeation through Pd complexes," Iwamura *et al.*, Advanced Technology Research Center, Mitsubishi Heavy Industries, Condensed Matter Nuclear Science – Proceedings of the 11th International Conference on Cold Fusion, J-P. Biberian, ed., World Scientific (2006) ISBN 981-256-640-6

This paper is also available online in the form of their original conference PowerPoint slides at:

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

Also online as a *Proceedings* paper published by World Scientific at:

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

Widom-Larsen theory explains MHI and Toyota data

Neutron-catalyzed transmutation: Cesium (Cs) → Praseodymium (Pr)

Condensed summary illustrates one possible LENR transmutation pathway

Series of neutron captures and beta (β^-) decays

$^{133}_{55}Cs + 1\text{ ulm n} \rightarrow {}^{134}_{55}Cs + \gamma$ (Q = 6.9 MeV; 2.1 yrs; $\sigma_{thermal} = 140$b)

$^{134}_{55}Cs + 1\text{ ulm n} \rightarrow {}^{135}_{55}Cs + \gamma$ (Q = 8.8 MeV; hl = 2.3 x 10^6 yrs; $\sigma_{thermal} = 8.9$b)

$^{135}_{55}Cs + 1\text{ ulm n} \rightarrow {}^{136}_{55}Cs + \gamma$ (Q = 6.8 MeV; hl = 13.2 days; $\sigma_{thermal}$ = ?)

$^{136}_{55}Cs + 1\text{ ulm n} \rightarrow {}^{137}_{55}Cs + \gamma$ (Q = 8.3 MeV; hl = 30.1 yrs; $\sigma_{thermal} = 0.25$b)

$^{137}_{55}Cs + 1\text{ ulm n} \rightarrow {}^{138}_{55}Cs + \gamma$ (Q = 4.4 MeV; hl = 33.4 min; $\sigma_{thermal}$ = ?)

$^{138}_{55}Cs + 1\text{ ulm n} \rightarrow {}^{139}_{55}Cs + \gamma$ (Q = 6.6 MeV; hl = 9.3 min; $\sigma_{thermal}$ = ?)

$^{139}_{55}Cs + 1\text{ ulm n} \rightarrow {}^{140}_{55}Cs + \gamma$ (Q = 4.4 MeV; hl = 64 sec; $\sigma_{thermal}$ = ?)

$^{140}_{55}Cs + 1\text{ ulm n} \rightarrow {}^{141}_{55}Cs + \gamma$ (Q = 5.5 MeV; hl = 25 sec; $\sigma_{thermal}$ = ?)

$^{141}_{55}Cs$ decays 100% via $\beta^- \rightarrow {}^{141}_{56}Ba + \gamma$ (Q = 5.3 MeV; hl = 18.3 min)

$^{141}_{56}Ba$ decays 100% via $\beta^- \rightarrow {}^{141}_{57}La + \gamma$ (Q = 3.2 MeV; hl = 3.9 hrs)

$^{141}_{57}La$ decays 100% via $\beta^- \rightarrow {}^{141}_{58}Ce + \gamma$ (Q = 2.5 MeV; hl = 32 days)

$^{141}_{58}Ce$ decays 100% via $\beta^- \rightarrow {}^{141}_{59}Pr$ ys (Q = 580 keV; stable)

Lattice Energy LLC

Widom-Larsen theory explains MHI and Toyota data

Neutron-catalyzed transmutation: Strontium (Sr) → Molybdenum (Mo)

Condensed summary illustrates one possible LENR transmutation pathway

Series of neutron captures and beta (β^-) decays

$^{88}_{38}\text{Sr} + 1\text{ ulm n} \rightarrow {}^{89}_{38}\text{Sr} + \gamma$ (Q = 6.4 MeV; 50.5 days)

$^{89}_{38}\text{Sr}$ decays 100% via $\beta^- \rightarrow {}^{89}_{39}\text{Y}$ + X-rays (Q = 1.5 MeV; stable)

$^{89}_{39}\text{Y} + 1\text{ ulm n} \rightarrow {}^{90}_{39}\text{Y} + \gamma$ (Q = 6.9 MeV; hl = 64hrs; $\sigma_{\text{thermal}} = 6.5\text{b}$)

$^{90}_{39}\text{Y} + 1\text{ ulm n} \rightarrow {}^{91}_{39}\text{Y} + \gamma$ (Q = 7.9 MeV; hl = 59 days; $\sigma_{\text{thermal}} = ?$)

$^{91}_{39}\text{Y} + 1\text{ ulm n} \rightarrow {}^{92}_{39}\text{Y} + \gamma$ (Q = 6.5 MeV; hl = 3.5 hrs; $\sigma_{\text{thermal}} = ?$)

$^{92}_{39}\text{Y} + 1\text{ ulm n} \rightarrow {}^{93}_{39}\text{Y} + \gamma$ (Q = 7.5 MeV; hl = 10.2 hrs; $\sigma_{\text{thermal}} = ?$)

$^{93}_{39}\text{Y}$ decays 100% via $\beta^- \rightarrow {}^{93}_{40}\text{Zr} + \gamma$ (Q = 2.9 MeV; hl = 1.5×10^6 yrs; $\sigma_{\text{thermal}} = <4\text{b}$)

$^{93}_{40}\text{Zr} + 1\text{ ulm n} \rightarrow {}^{94}_{40}\text{Zr} + \gamma$ (Q = 8.2 MeV; stable; $\sigma_{\text{thermal}} = 0.05\text{b}$)

$^{94}_{40}\text{Zr} + 1\text{ ulm n} \rightarrow {}^{95}_{40}\text{Zr} + \gamma$ (Q = 6.5 MeV; hl = 64 days; $\sigma_{\text{thermal}} = ?$)

$^{95}_{40}\text{Zr}$ decays 100% via $\beta^- \rightarrow {}^{95}_{41}\text{Nb}$ + X-rays (Q = 1.1 MeV; hl = 35 days; $\sigma_{\text{thermal}} = <7\text{b}$)

$^{95}_{41}\text{Nb} + 1\text{ ulm n} \rightarrow {}^{96}_{41}\text{Nb} + \gamma$ (Q = 6.9 MeV; hl = 23.4 hrs; $\sigma_{\text{thermal}} = ?$)

$^{96}_{41}\text{Nb}$ decays 100% via $\beta^- \rightarrow {}^{96}_{42}\text{Mo}$ … = 5.3 MeV; stable)

Widom-Larsen theory explains MHI and Toyota data

Cesium-seed LENR neutron-catalyzed element transmutation network

Legend

Note: to reduce visual clutter in the network diagram, gamma emissions (converted to infrared photons by heavy e^{-*} electrons) are not explicitly shown; similarly, except where specifically listed because a given branch cross-section is significant, beta-delayed decays also generally not shown

ULM neutron captures on isotopes: proceed from left to right; using the Brookhaven National Laboratory's online calculator, the estimated Q-value of the particular neutron capture reaction (MeV) is shown above the dark purple horizontal arrow

Beta$^-$ (β^-) decays: proceed from top to bottom; denoted with dark blue vertical arrow pointing downward; Q-value (MeV) of the decay is shown either to left or right

Beta-delayed decays accompanied by the emission of a free neutron: indicated by reddish orange arrows; proceed from right to left at a ~45 degree angle; Q-value is not shown; neutrons are not explicitly shown

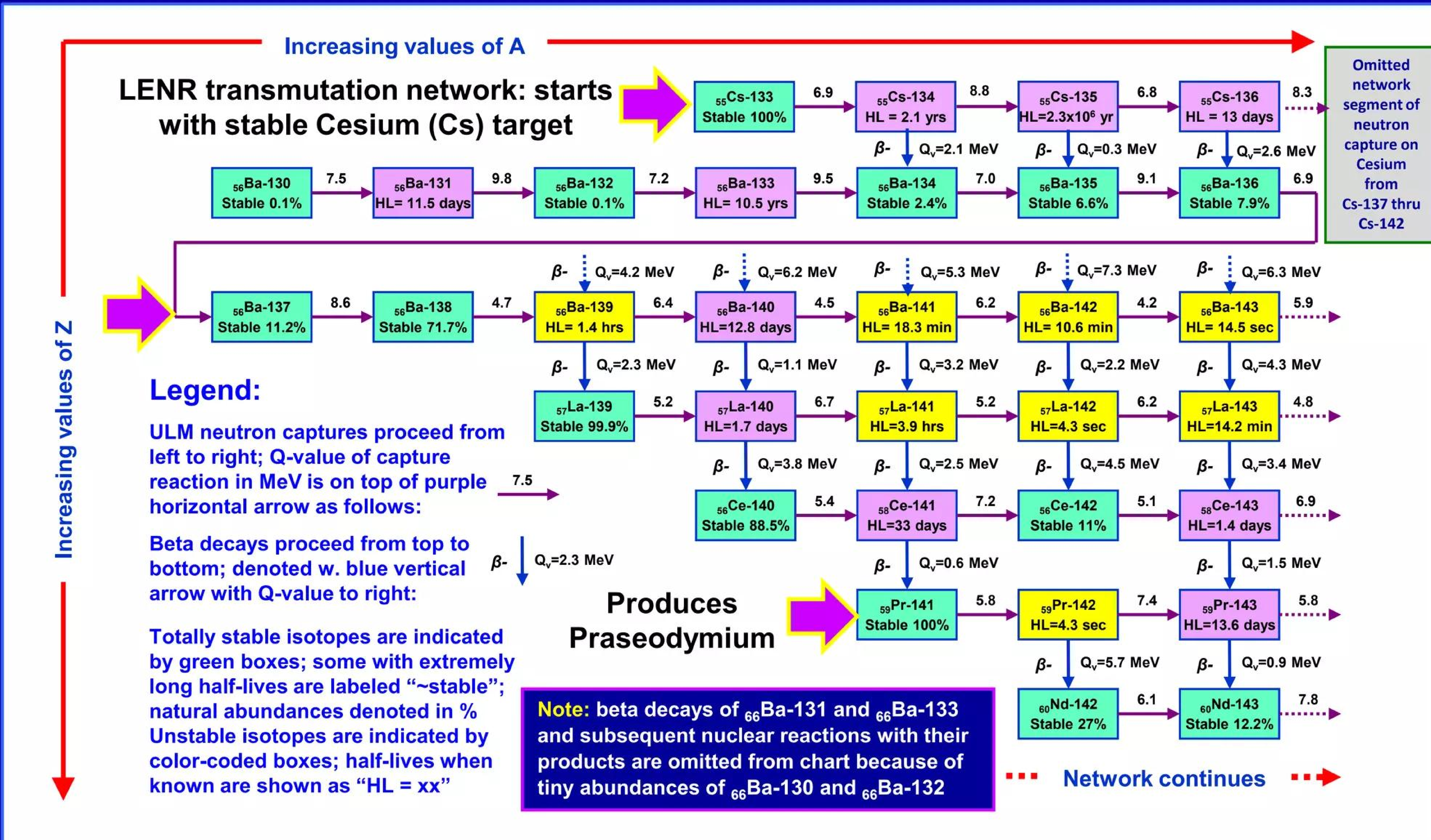
BR: means "branching ratio"; % of 100 shown if there is more than one significant nuclear decay pathway

Color coded half-lives of specific isotopes: when known, half-lives are shown as "HL = xx". Stable and quasi-stable isotopes (i.e., those with half-lives > or equal to 10^7 years) indicated by green boxes; isotopes with half-lives < 10^7 but > than or equal to 10^3 years indicated by light blue; those with half-lives < than 10^3 years but > or equal to 1 day are denoted by purplish boxes; half-lives of < 1 day in yellow; with regard to half-life, notation "? nm" means a particular isotope's HL has not yet been measured

Measured natural terrestrial abundances for stable isotopes: indicated with % symbol; for example - $_{83}Bi^{209}$ = 100% (essentially ~stable with half-life = 1.9×10^{19} yrs); $_{82}$Pb-205 ~stable with HL= 1.5×10^7 yrs; etc.

Lattice Energy LLC

Widom-Larsen theory explains MHI and Toyota data

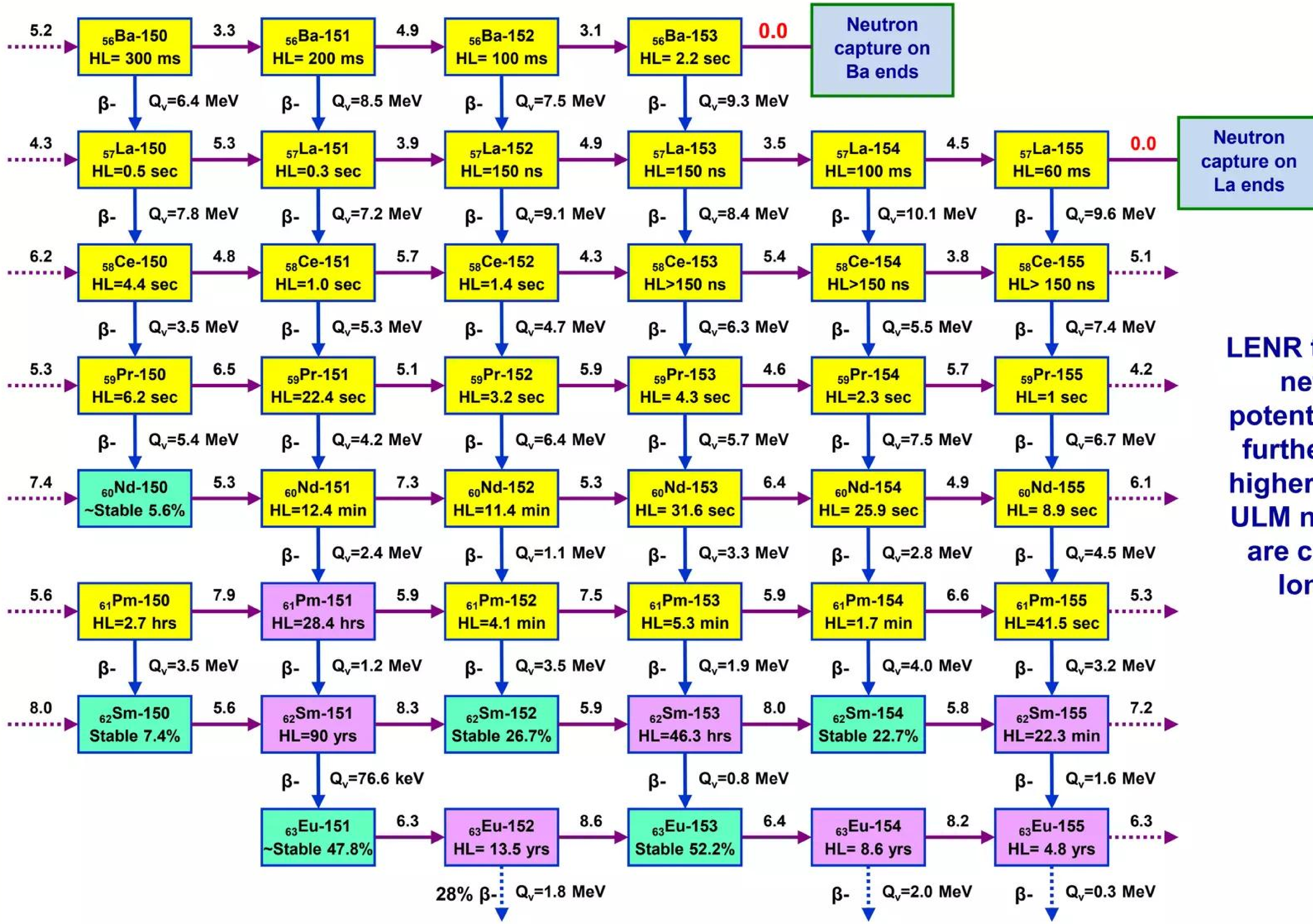


Lattice Energy LLC

Widom-Larsen theory explains MHI and Toyota data

Lattice Energy LLC

Widom-Larsen theory explains MHI and Toyota data



LENR transmutation network can potentially continue further up to even higher values of A if ULM neutron fluxes are continued for longer times

Oct. 2013: Toyota published data in peer-reviewed JJAP

Cesium

Praseodymium

Confirmed Mitsubishi results using MHI's method

Oct. 2013: Toyota published data in peer-reviewed *JJAP*

Confirm Mitsubishi's experimental method: transmutation of Cs → Pr

Source: http://jjap.jsap.jp/link?JJAP/52/107301/

"Inductively coupled plasma mass spectrometry study on the increase in the amount of Pr atoms for Cs-ion-implanted Pd/CaO multilayer complex with Deuterium permeation"
T. Hioki, N. Takahashi, S. Kosaka, T. Nishi, H. Azuma, S. Hibi, Y. Higuchi, A. Murase, and T. Motohiro
Japanese Journal of Applied Physics 52 pp. 107301-1 to 107301-8 (2013)

Abstract:

"To investigate the nuclear transmutation of Cs into Pr reported in this journal by Iwamura and coworkers, we have measured the amount of Pr atoms in the range as low as ~1 x 10^{10} cm^{-2} using inductively coupled plasma mass spectrometry for Cs-ion-implanted Pd/CaO multilayer complexes before and after Deuterium permeation. The amount of Pr was initially at most 2.0 x 10^{11} cm^{-2} and it increased up to 1.6 x 10^{12} cm^{-2} after Deuterium permeation. The increase in the amount of Pr could be explained neither by Deuterium permeation-stimulated segregation of Pr impurities nor by external contamination from the experimental environment during the permeation. No increase in Pr was observed for permeation with Hydrogen. These findings suggest that the observed increase in Pr with Deuterium permeation can be attributed to a nuclear origin, as reported by Iwamura and coworkers, although the amount of the increase in Pr is two orders of magnitude less than that reported by them."

Oct. 2013: Toyota published data in peer-reviewed *JJAP*

Confirm Mitsubishi's experimental method: transmutation of Cs → Pr

Source: http://jjap.jsap.jp/link?JJAP/52/107301/

"Inductively coupled plasma mass spectrometry study on the increase in the amount of Pr atoms for Cs-ion-implanted Pd/CaO multilayer complex with Deuterium permeation"

Conclusions:

"Using ICP-MS, we determined the concentration of Pr in the range as low as 1.0 x 10^{10} cm^{-2} for a variety of samples with respect to the Pd/CaO multilayer complex. The amounts of Pr in the D_2-permeated, Cs-ion-implanted multilayer complex samples were one order of magnitude larger than those in the non-D_2-permeated samples. The Pr atoms detected in the non-D_2-permeated samples were attributed to the Pr impurity contained in the Pd substrate used and the Pr atoms contaminated from the experimental environment of the Cs ion-implantation process in our laboratory. The observed increase in Pr atoms with deuterium permeation could not be explained by deuterium-stimulated segregation of the Pr contaminations onto the surface. Therefore, the observed increase in Pr with deuterium permeation is hard to explain in terms of chemical origins. Furthermore, no increase in Pr was observed by permeation with hydrogen. These findings seem to support the claim by Iwamura *et al.* that the nuclear transmutation of Cs into Pr occurs with deuterium permeation through Cs-deposited Pd/CaO multilayer complexes. The amount of Pr as the transmutation product was estimated to be on the order of 1 x 10^{12} cm^{-2} or ~0.1 ng/cm^2 in the present study. Thus, ICP-MS analysis on the order of 1 x 10^{10} cm^{-2} was required for observing the increase in Pr with deuterium permeation. The amount of the increased Pr was two orders of magnitude smaller than that reported by Iwamura and coworkers."

Discussion of Toyota paper published in *JJAP*

Cesium

↓

Praseodymium

Follows MHI's seminal publication by 11 years

Lattice Energy LLC

Discussion of Toyota paper published in *JJAP*

Confirm Mitsubishi's experimental method: transmutation of Cs → Pr

Schematic diagram of apparatus and multilayer thin-film heterostructure

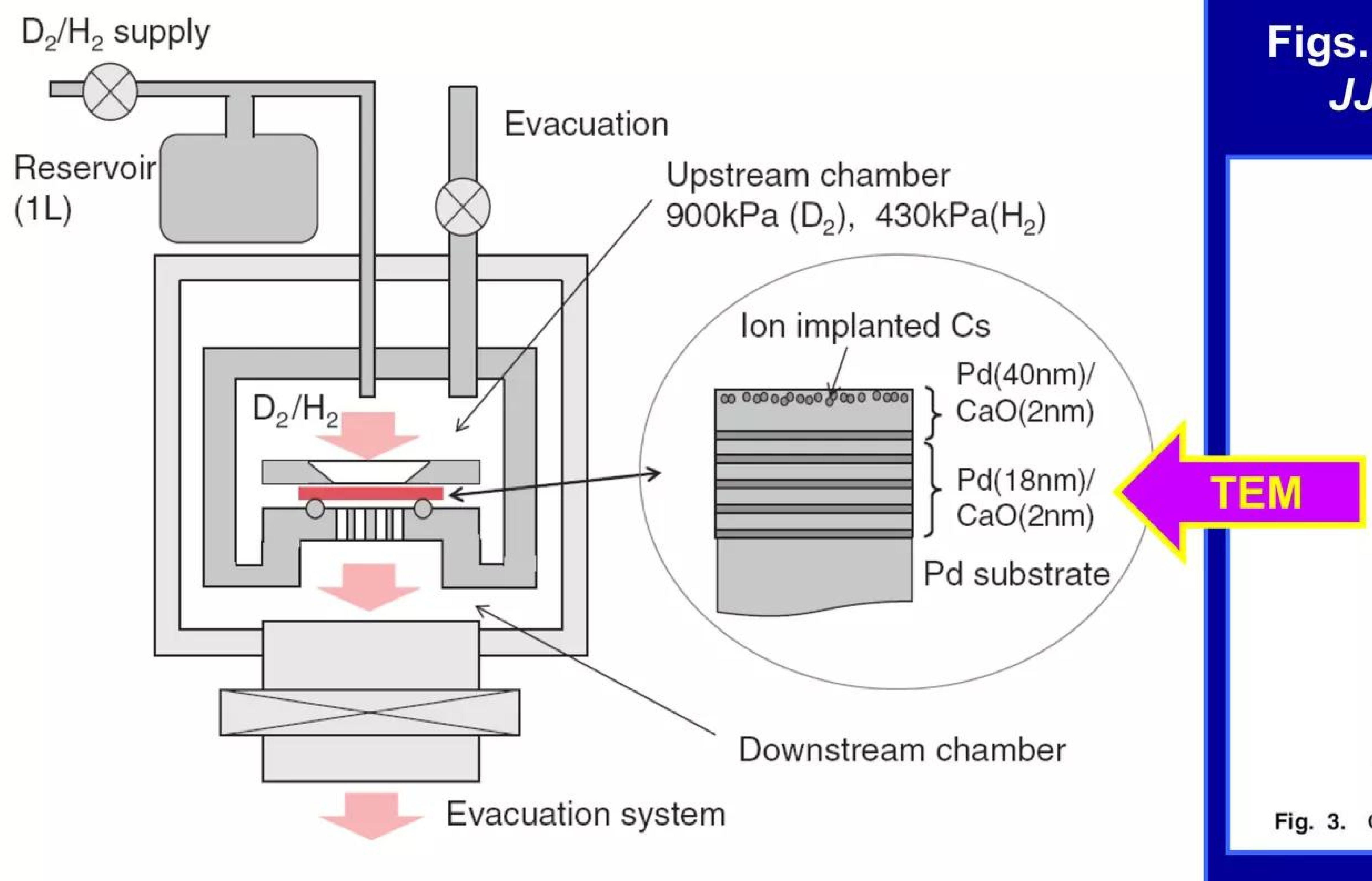


Fig. 1. (Color) Schematics of deuterium (/hydrogen) permeation system and Cs-ion-implanted Pd/CaO multilayer complex.

Figs. 1 and 3 are reproduced from *JJAP* paper by T. Hioki *et al*.

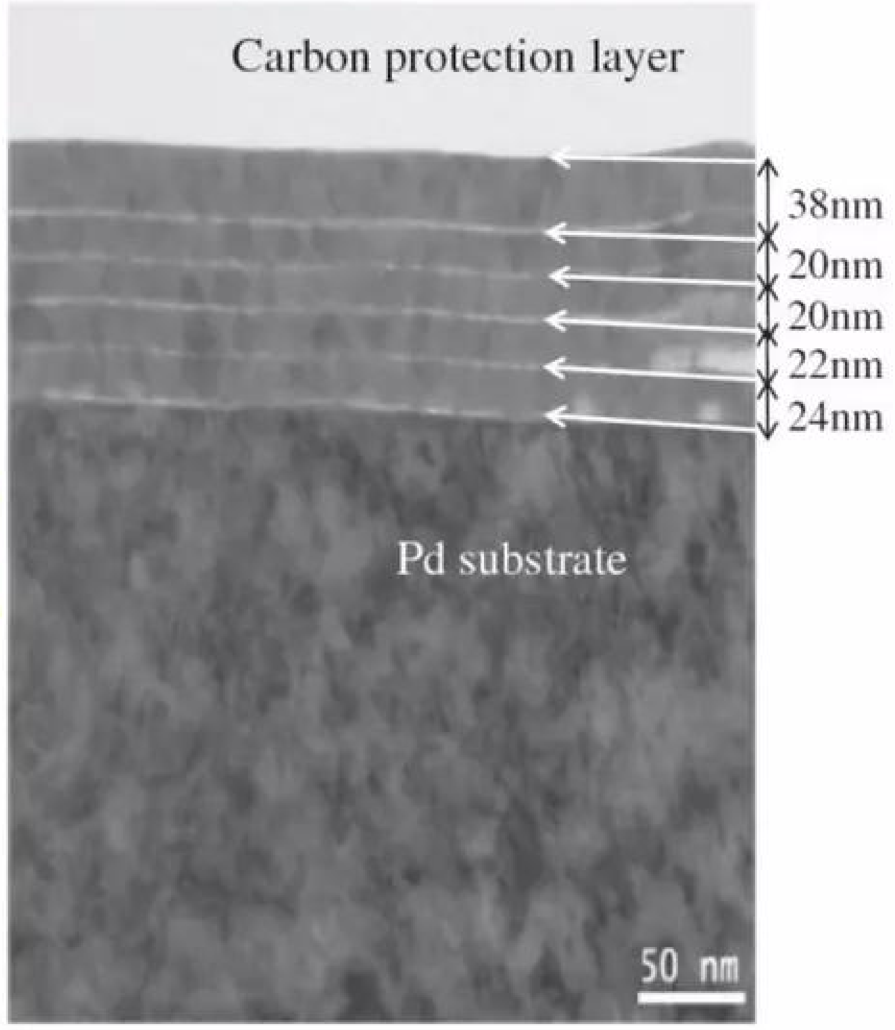


Fig. 3. Cross-sectional TEM view of the Pd/CaO multilayer complex.

Source *JJAP* (2013): http://jjap.jsap.jp/link?JJAP/52/107301/

Lattice Energy LLC

Discussion of Toyota paper published in *JJAP*

Confirm Mitsubishi's experimental method: transmutation of Cs → Pr

Carefully assessed crucial issue of possible experimental contamination with Pr

- ✓ Presence or absence of bonafide LENR transmutation products are often determined with post-experiment before-and-after analyses using stimulated X-ray emissions or best of all, mass spectroscopy methods
- ✓ Critics of reported LENR experimental results claiming that LENR transmutations were observed often try to invoke "contamination" arguments to dismiss such anomalous data
- ✓ Toyota's researchers made very careful, strenuous efforts to assess and measure the level of potential Pr contamination that might exist in any of the samples used in their experiments and/or in and around the laboratory environs

  Importantly, they concluded that: "Therefore, the partial dissolution of about 100 nm adopted in the ICP-MS analysis in this study enabled us to count all the Pr impurity atoms introduced by the ion implantation process. The maximum value of Pr contamination by the ion implantation process was 1.0×10^{11} cm^{-2}, which could only explain about 6% of the increment in Pr. Thus, both of the chemical contaminations can at most account for about 10% of the concentration of Pr detected in the Cs-implanted multilayer complex samples after the deuterium permeation treatment. Therefore, the observed increase in Pr atoms with deuterium permeation is hard to explain by chemical origins."

U.S. Naval Research Laboratory employees attempted to discredit Iwamura's 2002 results with spurious accusations of quasi-intentional lab Pr contamination; NRL motives are suspect:

NRL's machinations against MHI's reported Cs transmutation data were exposed by the *New Energy Times*; see recent reporting on this at:

http://news.newenergytimes.net/2013/10/22/journal-publishes-toyotas-independent-replication-of-mitsubishi-lenr-transmutation/

Quoting: "In a brief, five-minute rebuttal at a conference in Rome in 2009, Iwamura explained the multiple, logically inconsistent details of Kidwell's contamination scenario. (See "NRL 2008 - The LENR Null Results Laboratory" and "NRL 2009 - The LENR Null Results Laboratory, Again" ; see reports at:

http://newenergytimes.com/v2/news/2010/35/SR35904nrl2008.shtml

http://newenergytimes.com/v2/news/2010/35/SR35905nrl2009.shtml

Discussion of Toyota paper published in *JJAP*

Confirm Mitsubishi's experimental method: transmutation of Cs → Pr

Comments re results of light Hydrogen (H_2) experiments in light of W-L theory

Widom-Larsen theory of LENRs:

$$\text{Energy}_{\text{E-field}} + e^{-}_{sp} \rightarrow e^{-*}_{sp} + p^{+} \rightarrow n + \nu_e$$

$$\text{Energy}_{\text{E-field}} + e^{-}_{sp} \rightarrow e^{-*}_{sp} + d^{+} \rightarrow 2n + \nu_e$$

- ✓ In Widom-Larsen: Deuterium produces two times as many ULM neutrons as compared to using Hydrogen; all other things being equal, H_2 experiments will only transmute 50% as much Cs to Pr [2x difference in potentially produced Pr]
- ✓ Per Widom-Larsen: source of input energy is required to produce neutrons; unlike Mitsubishi (where gas pressures were identical in H_2 and D_2 experiments), Toyota used 53% lower pressures in H_2 experiments and then only ran two of them (vs. total of 6 D_2 experiments, only 3 of which clearly produced measurable amounts of Pr). Since no electric currents are used, this is roughly equivalent supplying ~50% less input energy to H_2 experiments [another 2x difference]
- ✓ With just these two factors alone, it would suggest 4x lower neutron production in H_2 experiments vs. similar D_2 runs

"Elemental analyses of Pd complexes: effects of D_2 gas permeation"
Y. Iwamura *et al.*
Japanese Journal of Applied Physics 41 pp. 4642 - 4650 (2002)

Author's copy: http://lenr-canr.org/acrobat/IwamuraYelementalaa.pdf

Quoting directly:

"D_2 gas is supplied at 1 atm on the Pd film side of the test piece and dissolves in D atoms at the surface. The D atoms intrude into the Pd thin film and diffuse through the Pd complex and then reach the surface of the bulk side, where they combine and are released as D_2 molecules."

"As a comparative study, we used H_2 gas instead of D_2 gas. The experimental results are shown in Fig. 6. In this case, only the gas is different; [all of] the other experimental conditions are all [exactly] the same as Fig. 4. We also find that Cs did not change and Pr never appeared. This suggests that deuterium is a necessary factor for observing the anomalous behavior of Cs and Pr."

Lattice Energy LLC

Discussion of Toyota paper published in *JJAP*

Confirm Mitsubishi's experimental method: transmutation of Cs → Pr

Comments re results of light Hydrogen (H_2) experiments in light of W-L theory

- ✓ In Toyota experiments, only 50% of 6 total D_2 runs showed detectable Pr; simple average across all six runs yields estimate of ~0.81 x 10^{12} or 8.1 x 10^{11} cm^{-2} ; simple average across two H_2 runs = avg. measured Pr of ~6.0(5.98) x 10^{10} cm^{-2} ; so amounts of Pr created during D^2 runs was likely only ~10x larger than what occurred on average in the H_2 runs
- ✓ There is another notable difference between two sets of D_2/H_2 experiments: in case of Hydrogen, thermal neutron capture cross-section on Hydrogen is substantially larger on Hydrogen (0.332 barns) than it is on Deuterium (0.510 millibarns) atoms. Converting from barns to SI units; one barn = 1 x 10^{-24} cm^2 and one millibarn = 1 x 10^{-27} cm^2; so after conversion H = .332 x 10^{-24} cm^2 and D = .510 x 10^{-27} cm^2; by this measure neutron capture on H would be 650x more likely than on D atoms; in other words, by factor of ~6.5 x 10^2

In Hydrogen permeation experiments, some percentage of total produced neutrons that might otherwise be captured on Cs (to make Pr) are 'lost' or 'wasted' to captures on Hydrogen atoms that instead make Deuterium (which has 650x lower neutron capture cross section). All other things being equal, on this basis alone one would expect H_2 experiments to transmute much smaller amounts Cs to Pr. Would it be full 650x more - probably not. But 5x to 10x may well be a reasonable 'haircut' estimate, so let us assume 5x. On previous slide we estimated factor of 4x. So 4 x 5 = 20x expected difference in Pr detected in D vs. H; this more than accounts for observed differential of 10x noted above

"Elemental analyses of Pd complexes: effects of D_2 gas permeation"
Y. Iwamura *et al.*
*Japanese Journal of Applied Phys*ics 41 pp. 4642 - 4650 (2002)

Author's copy: http://lenr-canr.org/acrobat/IwamuraYelementalaa.pdf

Quoting directly:

"D_2 gas is supplied at 1 atm on the Pd film side of the test piece and dissolves in D atoms at the surface. The D atoms intrude into the Pd thin film and diffuse through the Pd complex and then reach the surface of the bulk side, where they combine and are released as D_2 molecules."

"As a comparative study, we used H_2 gas instead of D_2 gas. The experimental results are shown in Fig. 6. In this case, only the gas is different; [all of] the other experimental conditions are all [exactly] the same as Fig. 4. We also find that Cs did not change and Pr never appeared. This suggests that deuterium is a necessary factor for observing the anomalous behavior of Cs and Pr."

Lattice Energy LLC

Discussion of Toyota paper published in *JJAP*

Confirm Mitsubishi's experimental method: transmutation of Cs → Pr

Neutron production rates in MHI method likely very low vs. electrochemical cells

- ✓ At right is reference to an arXiv preprint in which we perform a first-principles calculation of many-body collective neutron production rates in an electric-current-driven electrolytic chemical cell. We thus obtained W-L theoretically estimated rates of 10^{12} to 10^{14} neutrons per sec/cm^2; this range of values is in good agreement with the best-available published experimental measurements of such rates
- ✓ Again, according to the Widom-Larsen theory, input energy is required to produce neutrons that catalyze nuclear transmutations, the end-products of which are measured to estimate effective transmutation rates
- ✓ Using only relatively modest pressures and temperatures to supply required input energy, it is obvious that W-L neutron production rates in permeation experiments using the MHI method would be enormously lower than what would happen in current-driven electrolytic cells that have vastly greater amounts of input power available to produce neutrons. Neutron production rates via permeation will be extremely low to begin with; that being the case, when one takes previous adjustment factors of ~20x into account, it should not be very surprising that measured amounts of Pr produced would be much lower in H_2 vs. D_2 experiments

See: "Theoretical Standard Model rates of proton to neutron conversions near metallic hydride surfaces"
A. Widom and L. Larsen (2007) [12-page arXiv preprint]
http://arxiv.org/PS_cache/nucl-th/pdf/0608/0608059v2.pdf

Abstract: "The process of radiation induced electron capture by protons or deuterons producing new ultra low momentum neutrons and neutrinos may be theoretically described within the standard field theoretical model of electroweak interactions. For protons or deuterons in the neighborhoods of surfaces of condensed matter metallic hydride cathodes, such conversions are determined in part by the collective plasma modes of the participating charged particles, e.g. electrons and protons or deuterons. The radiation energy required for such low energy nuclear reactions may be supplied by the applied voltage required to push a strong charged current across a metallic hydride surface employed as a cathode within a chemical cell. The electroweak rates of the resulting ultra-low momentum neutron production are computed from these considerations."

Eqs. 108 and 109

$$\varpi_2 = \nu(\beta - \beta_0)^2 \quad \text{above threshold} \quad \beta > \beta_0. \qquad (108)$$

The expected range of the parameter ν for hydrogen-loaded cathodes is approximately

$$10^{12}\ \frac{\text{Hz}}{\text{cm}^2} < \nu < 10^{14}\ \frac{\text{Hz}}{\text{cm}^2} \qquad (109)$$

Lattice Energy LLC

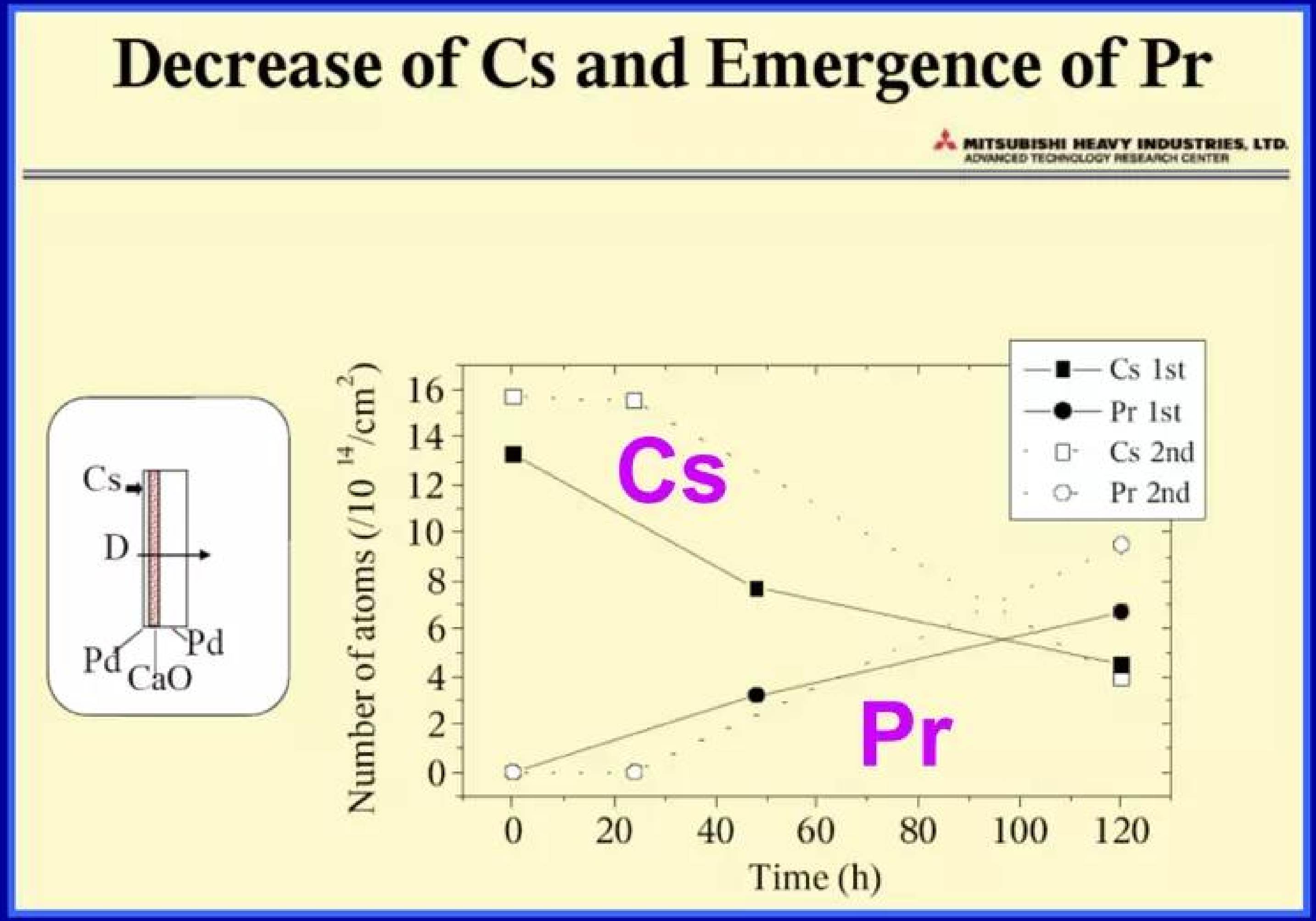
Discussion of Toyota paper published in *JJAP*

Confirm Mitsubishi's experimental method: transmutation of Cs → Pr

Wrap-up of Lattice's final conclusions about Toyota's *JJAP* experimental results

- ✓ Lattice agrees with Toyota that their experimental results do indeed confirm that Mitsubishi researchers truly observed the transmutation of Cesium (Cs) to Praseodymium (Pr) using MHI's well-documented, published Hydrogen isotope permeation method
- ✓ All the experimental results of Mitsubishi and Toyota are fully explained by neutron-catalyzed reactions and decays as specified in the Widom-Larsen theory of LENRs, as we have shown by examples provided herein
- ✓ Lattice would beg to differ with Toyota and Mitsubishi's conclusion that H_2 experiments show a null result for transmutation of Cs into Pr. Herein, we have shown how that conclusion may be erroneous because even if Pr was truly being produced during H_2 runs, it could easily be at rates that would be below the levels of detection, given the various adjustment factors we have explained
- ✓ Interestingly, Mitsubishi cited the Widom-Larsen theory in its 2012 American Nuclear Society presentation; Toyota did not do so in its Oct. 2013 *JJAP* paper

Cause-and-effect is obvious in timeline plot of Mitsubishi's data: observed number of Cesium (Cs) atoms simultaneously goes down at roughly the same rate as number of Praseodymium (Pr) atoms goes up



Source: Mitsubishi presentation at ICCF-18 (2013)

Discussion of Toyota paper published in *JJAP*

"Table I. List of samples … and … amounts of Pr detected by ICP-MS"

Table I. is reproduced from *JJAP* paper by T. Hioki *et al.*

Jpn. J. Appl. Phys. **52** (2013) 107301 — T. Hioki et al.

Table I. List of samples: the preparation conditions and the amounts of Pr detected by ICP-MS. The amount of Pr lower than the detection limit is denoted by <DL.

Sample number	Multilayer	Cs implantation	D_2 or H_2 permeation	Maximum upstream pressure (kPa)	Permeation temperature (K)	Average D_2 or H_2 flux (sccm)	Total permeated D_2 or H_2 (L)	Dissolution	Amount of Pr (cm^{-2})
#1	Yes	Yes	Yes (D_2)	900	423	5.3	43	Partial	1.47×10^{12}
#2	Yes	Yes	Yes (D_2)	900	423	2.6	74	Partial	2.12×10^{12}
#3	Yes	Yes	Yes (D_2)	900	423	2.5	40	Partial	1.27×10^{12}
#4	Yes	No	Yes (D_2)	900	423	2.0	27	Partial	<DL
#5	No	No	Yes (D_2)	900	423	2.8	42	Partial	<DL
#6	No	No	Yes (D_2)	900	423	3.0	48	Partial	<DL
#7	Yes	Yes	Yes (H_2)	430	423	4.4	76	Partial	5.13×10^{10}
#8	No	Yes	Yes (H_2)	430	423	5.5	70	Partial	6.83×10^{10}
#9	Yes	Yes	No		—			Partial	9.77×10^{10}
#10	Yes	Yes	No		—			Partial	1.00×10^{11}
#11	No	No	No		—			Partial	<DL
#12	No	No	No		—			Partial	<DL
#13	No	No	No		—			Partial	<DL
#14	Yes	No	No		—			Partial	<DL
#15	Yes	No	No		—			Partial	<DL
#16	Yes	No	No		—			Partial	<DL
#17	No	Yes	No		—			Partial	2.48×10^{10}
#18	No	Yes	No		—			Partial	2.31×10^{10}
#19	No	No	No		—			Total	2.33×10^{10}
#20	No	No	No		—			Total	8.98×10^{10}
#21	No	No	No		—			Total	7.89×10^{10}

D_2

H_2

No Hydrogen

Source *JJAP* (2013): http://jjap.jsap.jp/link?JJAP/52/107301/

Lattice Energy LLC

Discussion of Toyota paper published in *JJAP*

"Fig. 7 Comparison of…amount of Pr detected by ICP-MS for…samples"

Fig. 7 is reproduced from *JJAP* paper by T. Hioki *et al.*

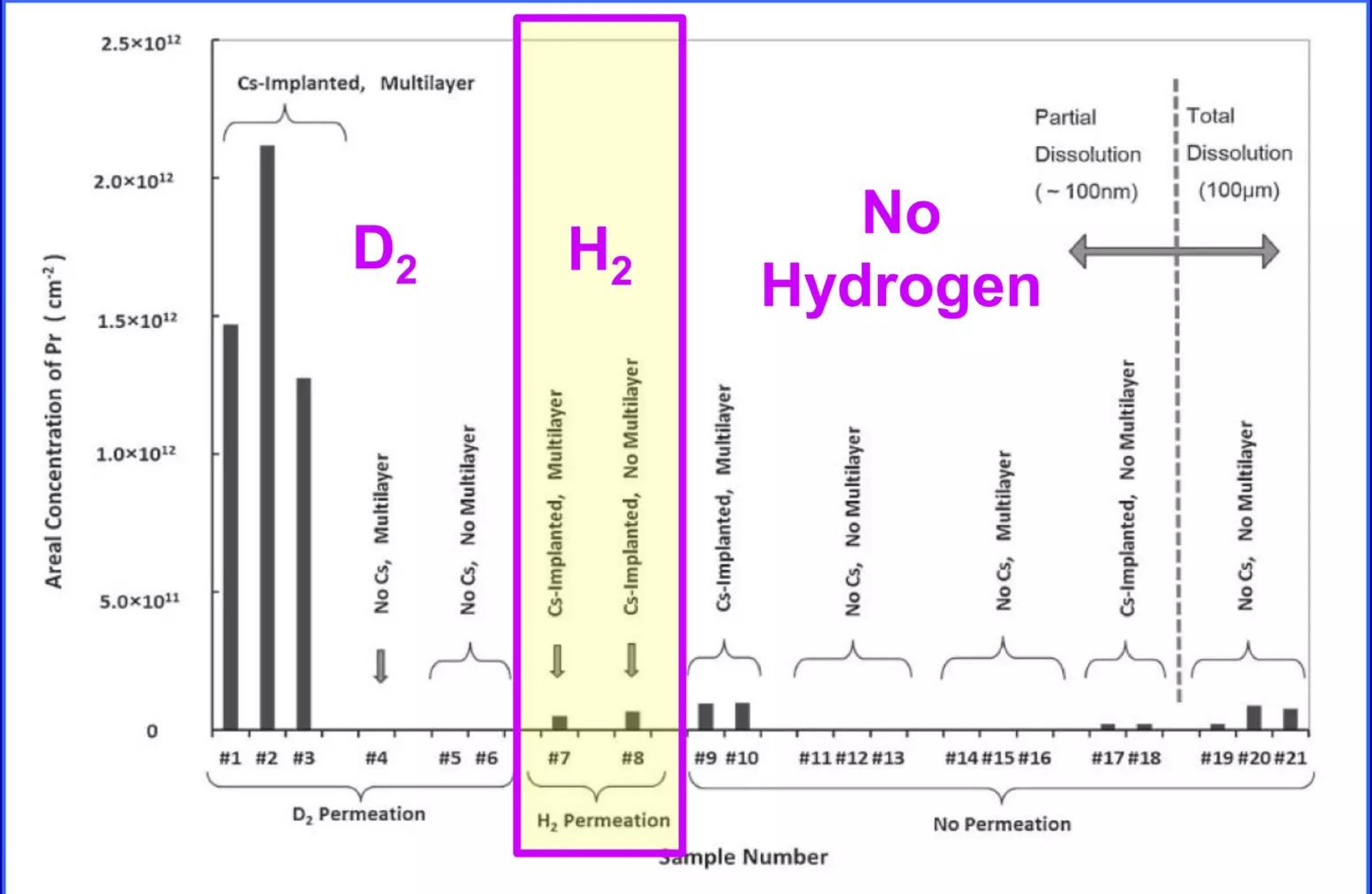


Fig. 7. Comparison of the amount of Pr detected by ICP-MS for the samples studied.

Source *JJAP* (2013): http://jjap.jsap.jp/link?JJAP/52/107301/

Mitsubishi confirmed Nagaoka's 1925 experiments

Tungsten

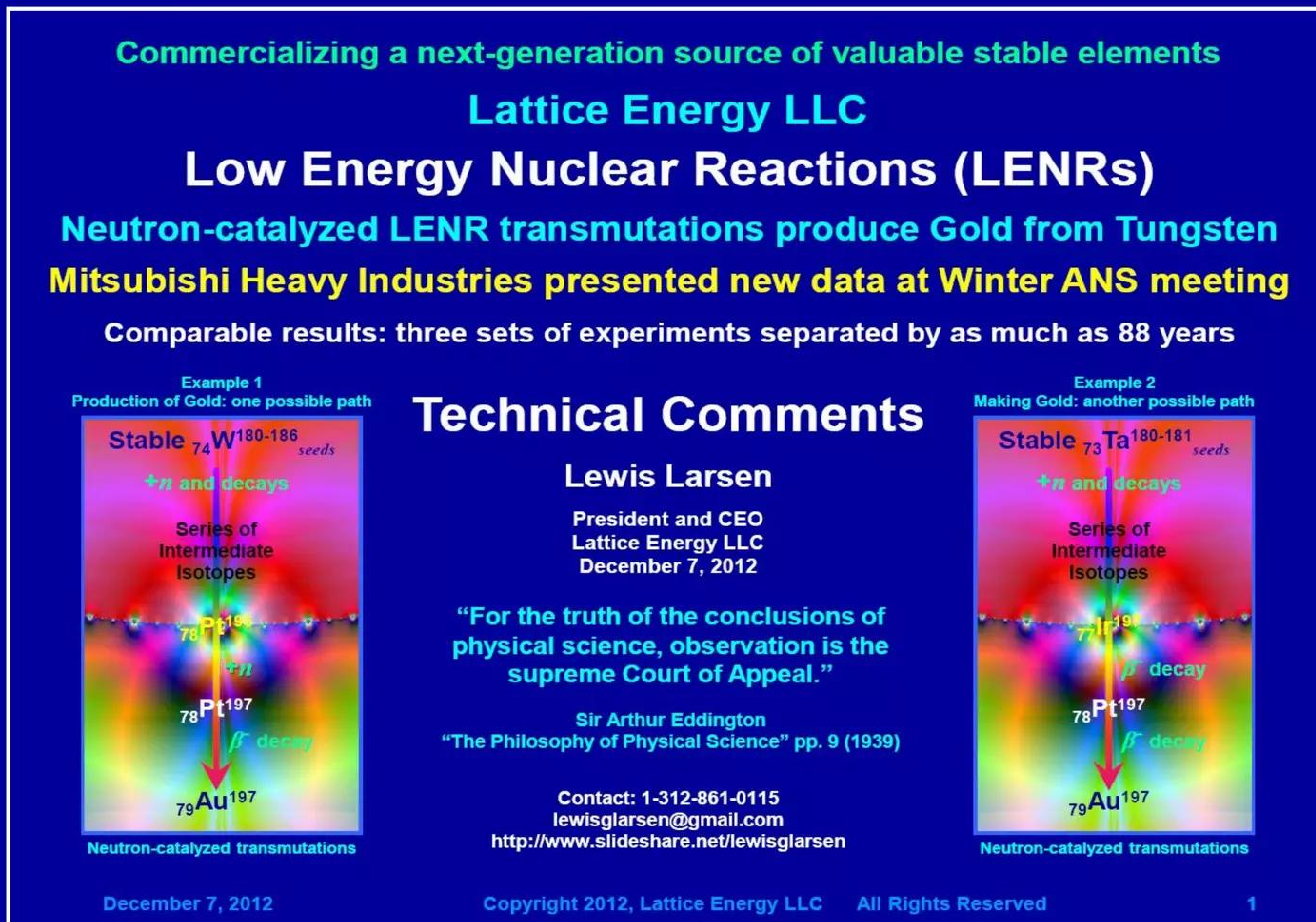
Gold

Neutron captures and decays produced results

Lattice Energy LLC

Mitsubishi confirmed Nagaoka's 1925 experiments

Confirmed LENR transmutation path vector: Tungsten → stable Gold



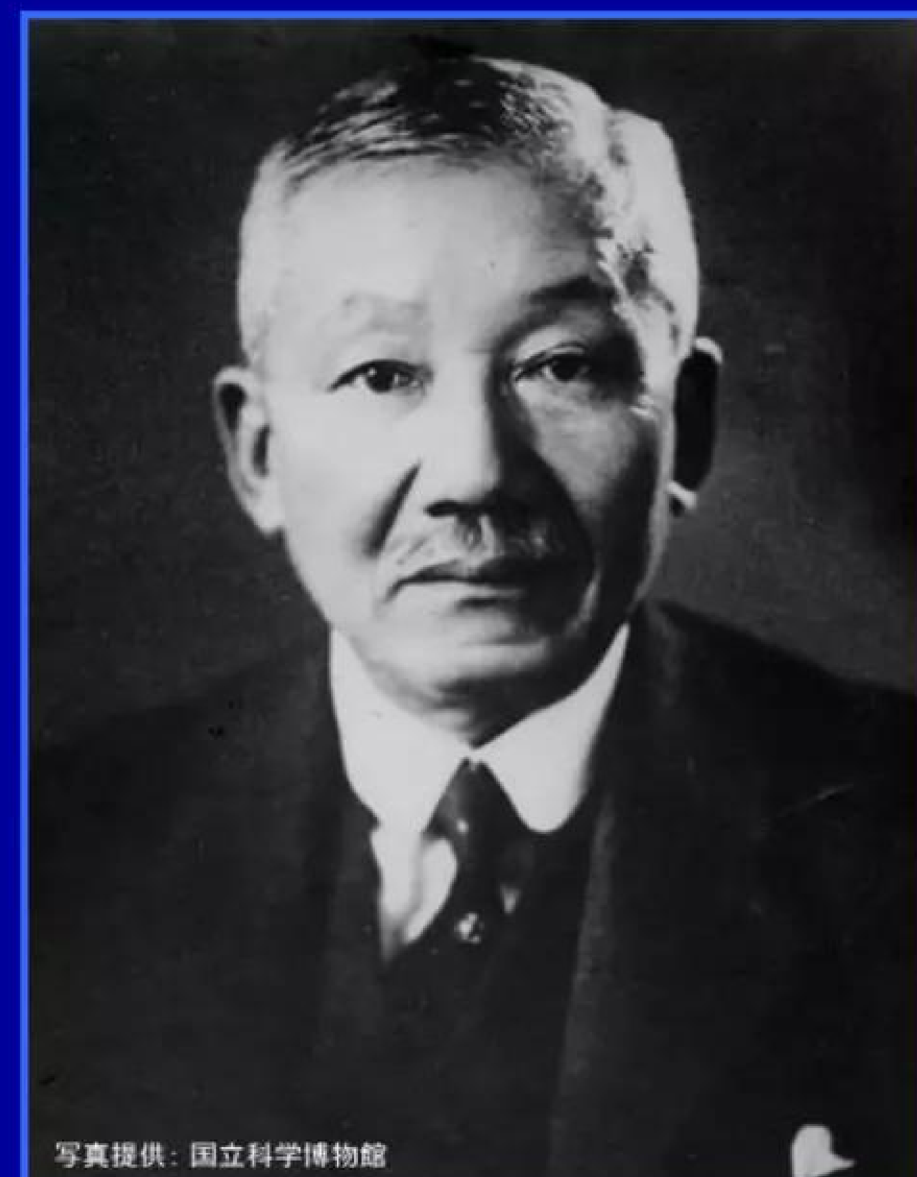
Source: http://www.slideshare.net/lewisglarsen/lattice-energy-llc-lenr-transmutation-networks-can-produce-golddec-7-2012

Mitsubishi confirmed Nagaoka’s 1925 experiments

Nagaoka *et al*. produced Gold from Tungsten via electric arcs in oil

Prof. Hantaro Nagaoka, famous Japanese physicist (1865 - 1950)

A brilliant, visionary man far ahead of his own time



“The [high-current electric arc] experimental procedure here sketched cannot be looked upon as the only one for effecting transmutation [of other elements into Gold]; probably different processes will be developed and finally lead to industrial enterprises … Experiments with various elements may lead to different transmutations, which will be of significance to science and industry. Meagre as is the result, I wish to invite the attention of those interested in the subject so that they may repeat the experiment with more powerful means than are available in the Far East.”

Prof. Hantaro Nagaoka in *“*Letters to the Editor*,”* *Nature*, July 18, 1925

Lattice Energy LLC

Mitsubishi confirmed Nagaoka’s 1925 experiments

Nagaoka *et al*. produced Gold from Tungsten via electric arcs in oil

Transmutations with electric arcs were widely reported and discussed in 1920s

- ✓ **Unlike, comparatively unknown Wendt & Irion team at the Univ. of Chicago (1922), Nagaoka was world-renowned physicist and one of the most preeminent scientists in Japan when he began his high-current discharge transmutation experiments in September 1924**
- ✓ **For an appreciation of Hantaro’s high scientific stature, please see Wikipedia article:**

  http://en.wikipedia.org/wiki/Hantaro_Nagaoka
- ✓ **Nagaoka was contemporary competitor of Ernest Rutherford; Hantaro’s “Saturn model” of the atom was only competing model cited by Rutherford in his seminal 1911 paper on atomic nuclei**
- ✓ **Given the very international character of science even at that time, it is very likely that Nagaoka was aware of worldwide controversy swirling around Wendt & Irion’s exploding wire experiments and of Rutherford's short but devastating critical attack on them in *Nature***
- ✓ **It is also quite likely that Hantaro was aware of Robert Millikan’s very supportive views on subject of triggering transmutations with electric arcs (note: Millikan had just won a Nobel prize in physics)**
- ✓ **Lastly, he must have known about Miethe & Stammreich’s work in Germany; they claimed to have changed Mercury into Gold in a high-voltage Mercury vapor lamp, “The reported transmutation of Mercury into Gold,” *Nature* 114 pp. 197 - 198 (1924)**

Please see:

“Preliminary note on the transmutation of Mercury into Gold,” H. Nagaoka, *Nature* 116 pp. 95 - 96 (1925)

Available for purchase on *Nature* archives at:

http://www.nature.com/nature/journal/v116/n2907/abs/116095a0.html

Abstract:

"The experiment on the transmutation of mercury was begun in September 1924, with the assistance of Messrs. Y. Sugiura, T. Asada and T. Machida. The main object was to ascertain if the view which we expressed in NATURE of March 29, 1924, can be realised by applying an intense electric field to mercury atoms. Another object was to find if the radio-active changes can be accelerated by artificial means. From the outset it was clear that a field of many million volts/cm. is necessary for the purpose. From our observation on the Stark effect in arcs of different metals (*Jap. Journ. Phys*., vol. 3, pp. 45â€“73) we found that with silver globules the field in a narrow space very near the metal was nearly 2 Ã -10^5 volts/cm. with terminal voltage of about 140. The presence of such an intense field indicated the possibility of obtaining the desired strength of the field for transmutation, if sufficient terminal voltage be applied. Though the above ratio of magnification would be diminished with high voltage, the experiment was thought worth trying, even if we could not effect the transmutation with the apparatus at hand."

Lattice Energy LLC

Mitsubishi confirmed Nagaoka's 1925 experiments

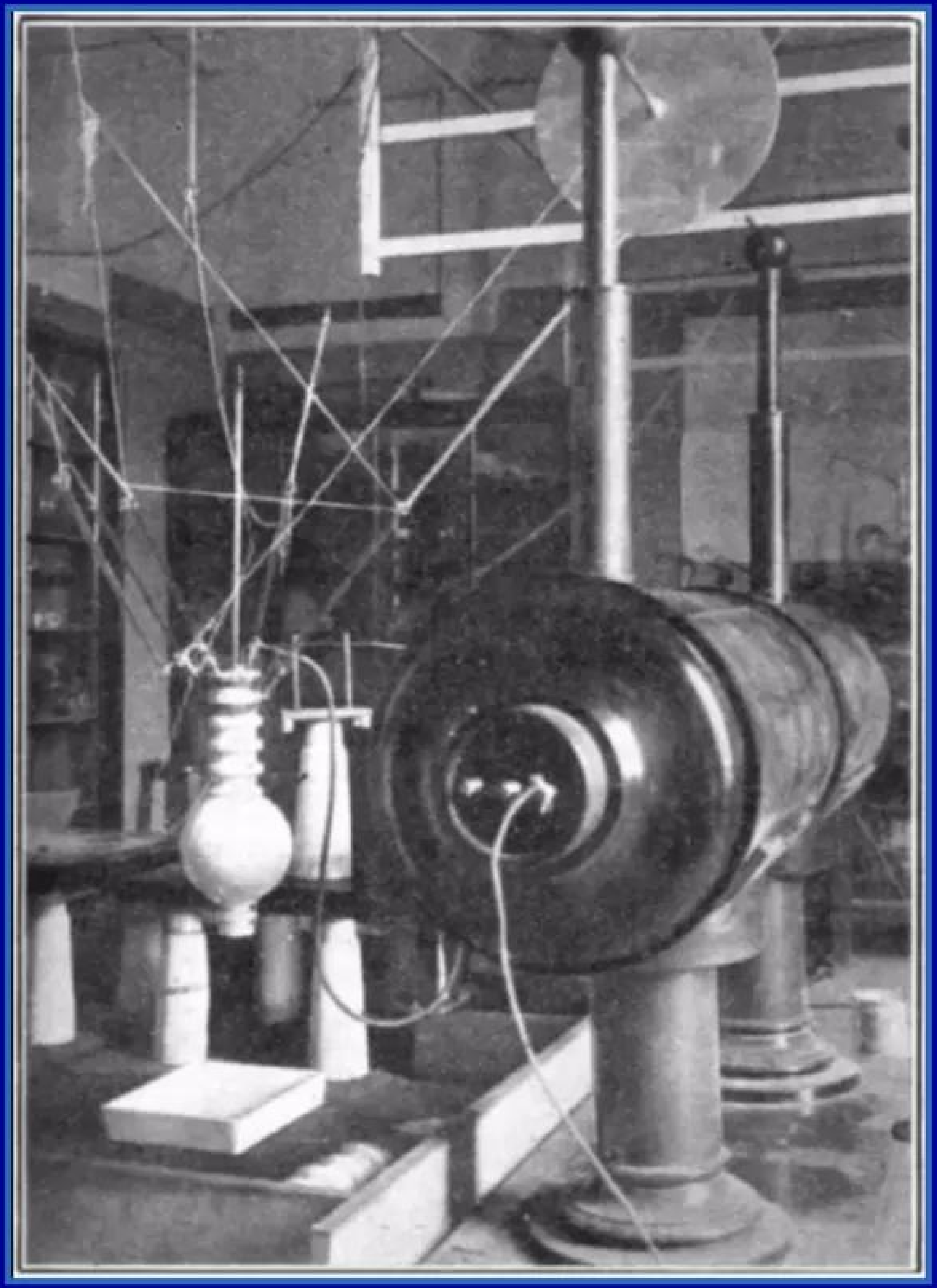
Nagaoka *et al*. produced Gold from Tungsten via electric arcs in oil

Observed macroscopic flecks of Gold and Platinum visible to the naked eye

Essence of Prof. Nagaoka's brilliant experiments:

- ✓ In the simplest terms: Prof. Nagaoka created a powerful electric arc discharge between a spark gap comprising two metallic, Thorium-oxide-free Tungsten (W) electrodes (supplied by Tokyo Electric Company) bathed in a dielectric liquid "paraffin" (today referred to as "transformer oil;" general formula C_nH_{2n+2}) that was 'laced' with liquid Mercury (Hg)
- ✓ Depending on experiment, arcing between Tungsten electrodes in oil was continued for 4 - 15 hours until, quoting, " … the oil and mercury were mixed into a black pasty mass." Please note that Mercury readily forms amalgams with many different metals, including Gold (Au) and Tungsten (W)
- ✓ Small flecks of Gold were sometimes quite visible to the naked eye in "black masses" produced at the end of a given experiment. They also noted that, "The Gold obtained from Mercury seems to be mostly adsorbed to Carbon."
- ✓ Microscopic assays were conducted by, "heating small pieces of glass with the Carbon," to form a so-called "Ruby glass" that can be used to infer the presence of gold colloids from visual cues very apparent under a microscope
- ✓ Critics complained about the possibility that the Gold observed was some sort of "contamination." Responding to critics, Nagaoka *et al.* further purified literally everything they could think of and also made certain that the lab environs were squeaky clean; they still kept seeing anomalous Gold. Also, in some experiments they also observed, "a minute quantity of white metal." Two years later in 1926, Nagaoka reported to Scientific American that they had finally been able to identify the "white metal" --- it was metallic Platinum (Pt)

Fig. 1 – Apparatus for the electric discharge
H. Nagaoka, *Nature* July 18, 1925



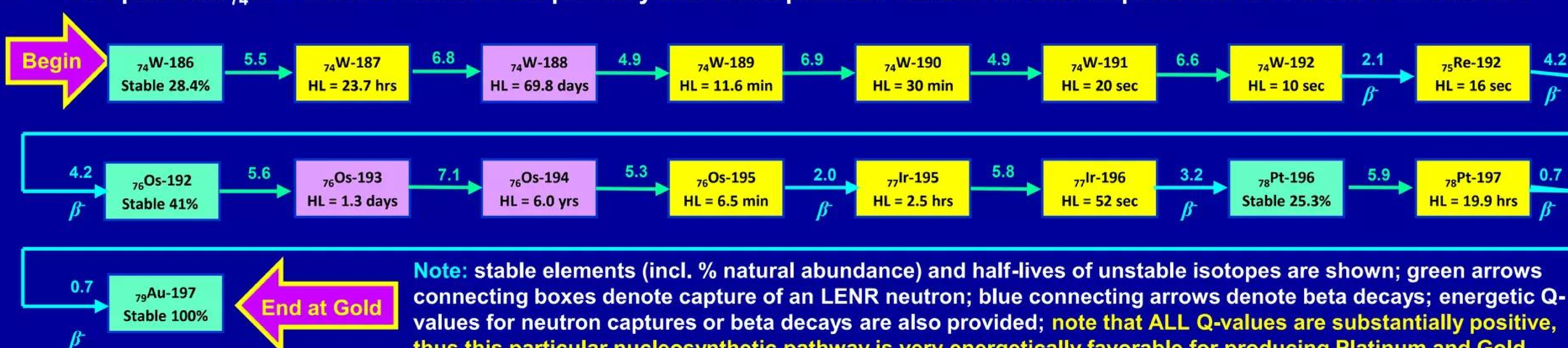
Mitsubishi confirmed Nagaoka's 1925 experiments

Nagaoka *et al*. produced Gold from Tungsten via electric arcs in oil

Widom-Larsen theory can fully explains all of Nagaoka's experimental results

Based on WLT $_{74}W^{180}$ LENR network , what sequence of reactions could have produced observed Gold and Platinum?

- ✓ **All of the ingredients for LENRs to occur were in fact present: hydride-forming metal found therein was Tungsten (sadly, Nagaoka was unaware that Mercury was more-or-less a 'red herring'); which was in contact with abundant Hydrogen (protons) in transformer oil (C_nH_{2n+2}); the Born-Oppenheimer approximation broke-down on surfaces of electrodes; and finally, there were large non-equilibrium fluxes of charged particles --- electrons in the high-current arc discharges. Unbeknownst to Nagaoka, his high-current arcs probably also produced small amounts of fullerenes, carbon nanotubes, and perhaps even a little graphene. ULM neutron production rates via W-L weak interaction could have been quite substantial in his high-electric-current-driven experimental system because of large energy inputs**
- ✓ **What could have happened in Nagaoka's experiments was that Tungsten-seed, ULM neutron-catalyzed nucleosynthetic networks spontaneously formed. What follows is but one example of an energetically favorable network pathway that could produce detectable amounts of the only stable Gold isotope, $_{197}Au$, within ~4 hours (shortest arc discharge period after which Au was observed). Other alternative viable LENR pathways can produce unstable Gold isotopes, e.g., $_{198}Au$ with half-life = 2.7 days and $_{199}Au$ with HL = 3.1 days (both would be around for a time at end of a successful experiment)**
- ✓ **One possible $_{74}W^{180}$-seed LENR network pathway that could produce Pt/Au in as little elapsed time as 4-5 hrs is as follows:**



Note: stable elements (incl. % natural abundance) and half-lives of unstable isotopes are shown; green arrows connecting boxes denote capture of an LENR neutron; blue connecting arrows denote beta decays; energetic Q-values for neutron captures or beta decays are also provided; note that ALL Q-values are substantially positive, thus this particular nucleosynthetic pathway is very energetically favorable for producing Platinum and Gold

Mitsubishi confirmed Nagaoka's 1925 experiments

Nagaoka *et al*. produced Gold from Tungsten via electric arcs in oil

No one ever tried to repeat Nagaoka's experiments during the 1920s. Why???

Nagaoka's reported results most likely were right , i.e., Au and Pt were produced:

- ✓ Plausible LENR nucleosynthetic pathway shown in the previous Slide suggests that Nagaoka et al.'s claimed observations of macroscopically visible particles of Gold in their ca. 1920s electric arc experiments in transformer oil could very well have been correct
- ✓ Note that stable Gold can also be produced via neutron capture on stable $_{80}Hg^{196}$ which creates unstable $_{80}Hg^{197}$ that has a half-life of 2.7 days and decays via electron capture into stable $_{79}Au^{197}$. However, natural abundance (0.15%) of $_{80}Hg^{19}$ initially present in Nagaoka's 1920s experiments was so low that this alternative pathway cannot plausibly account for observed production of macroscopically visible quantities of Au and Pt flecks
- ✓ It is puzzling why this seemingly fruitful line of inquiry appears to have died-out worldwide by the time Chadwick experimentally verified the neutron's existence in 1932? Oddly, it does not appear that anyone else ever tried to exactly duplicate Nagaoka's experiments. However, there were well-publicized failures to replicate Miethe & Stammreich's Gold experiments that were extensively chronicled in Scientific American. Interestingly, Miethe's experimental apparatus consisted of Mercury arc lamps with Tungsten electrodes inside evacuated quartz tubes; no transformer oil was present in those arcs. Perhaps Nagaoka's decision to use oil was exceedingly fortuitous: by doing so, he inadvertently guaranteed that his apparatus contained enormous quantities of hydrogen for making ULM neutrons
- ✓ Please take note of the quotation from Prof. Nagaoka reproduced on an earlier Slide. In saying what he said, Hantaro clearly believed that some sort of commercial transmutation technology would eventually be developed at some point in the future. Thus, in our opinion not only was he a humble, brilliant scientist; he was also a rather bold visionary thinker --- truly a man far ahead of his own time
- ✓ Interestingly, in the present era it is certainly possible that minute quantities of Gold are actually being produced in automobile catalytic converters via the transmutation of some Platinum present in the converters: at right, please see citation to a 2003 paper in *Applied Geochemistry* and URL to yet another Lattice SlideShare presentation dated June 25, 2010

Re catalytic converters as sources of Gold:

G. Dongarra, D. Varrica, and G. Sabatino, "Occurrence of Platinum, Palladium, and Gold in pine needles of Pinus pinea from the city of Palermo (Italy)," *Applied Geochemistry* 18 pp. 109-116 (2003)

Quoting: "Preliminary data on the presence of Pt, Pd and Au in airborne particulate matter from the urban area of Palermo (Sicily, Italy) are presented. They were obtained by analysing 40 samples of pine needles (*Pinus pinea L.*) collected in and around the city. Observed concentrations range from 1 to 102 µg/kg for Pt, 1 to 45 µg/kg for Pd and 22 to 776 µg/kg for Au. Platinum and Pd concentrations in pine needles are up to two orders of magnitude higher than their crustal abundances. They exhibit a high statistical correlation (R^2=0.74) which suggests a common origin."

"Precious metal concentrations measured within the city centre are much higher than those occurring outside the town. The distribution patterns of Pt and Pd in the study area are compared to the distributions of Au and Pb. Gold is enriched at the same sites where Pt and Pd are enriched, while Pb shows some discrepancies. The most probable local source of all of these elements is traffic. Average Pt and Pd emissions in the city area are estimated to be about 136 and 273 g/a, respectively."

Discussed in Lattice presentation found at URL:

http://www.slideshare.net/lewisglarsen/lattice-energy-llc-len-rs-in-catalytic-convertersjune-25-2010

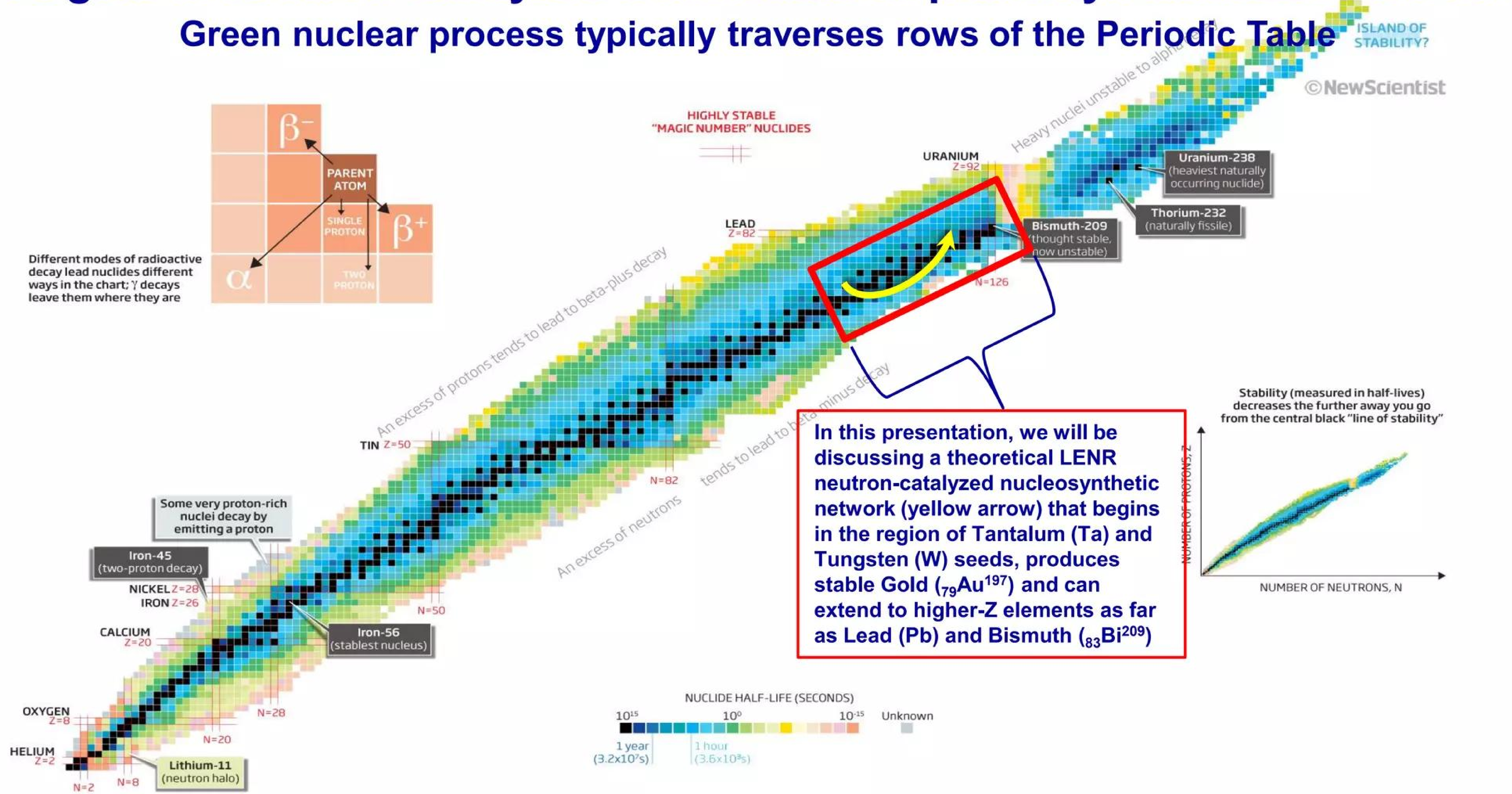
Lattice Energy LLC

Mitsubishi confirmed Nagaoka’s 1925 experiments

Tungsten seed LENR transmutation network shown in isotopic space

Region of neutron-catalyzed transmutation pathways discussed herein

Green nuclear process typically traverses rows of the Periodic Table



In this presentation, we will be discussing a theoretical LENR neutron-catalyzed nucleosynthetic network (yellow arrow) that begins in the region of Tantalum (Ta) and Tungsten (W) seeds, produces stable Gold ($_{79}Au^{197}$) and can extend to higher-Z elements as far as Lead (Pb) and Bismuth ($_{83}Bi^{209}$)

Mitsubishi confirmed Nagaoka's 1925 experiments

Widom-Larsen theory Tungsten-seed LENR transmutation network

Series of neutron captures and nuclear decays that transmute W → Pt → Au

- ✓ We will now examine a hypothetical Widom-Larsen theory LENR transmutation network that begins with neutron captures on Tantalum (Ta) and Tungsten (W) seeds
- ✓ Explanatory legend for network diagrams appears on the next slide
- ✓ ${}_{74}W^{180}$-seed network produces Gold (Au) and Platinum (Pt); if sufficiently high neutron fluxes are maintained for enough time, it can reach Bismuth (Bi)
- ✓ While unstable intermediate network products undergo nuclear decays, their half-lives are generally short (especially those that are more neutron-rich); this network does not produce significant amounts of dangerous long-lived radioactive isotopes
- ✓ According to the WLT, in condensed matter systems LENRs occur in many tiny nm- to micron-scale surface sites or patches that only live for several hundred nanoseconds before they die; such sites can form and re-form spontaneously
- ✓ Need input energy to make ultra cold neutrons that catalyze LENR transmutations
- ✓ Importantly, there is very intriguing experimental evidence that this nucleosynthetic network occurs in laboratories, catalytic converters in vehicles, and out in Nature

Mitsubishi confirmed Nagaoka's 1925 experiments

Legend

Neutron capture and nuclear decay processes:

ULM neutron captures: proceed from left to right except for upper-left corner; Q-value of capture reaction (MeV) in green either above or below horizontal arrow. →

Beta⁻ (β^-) decays: proceed from top to bottom; denoted with bright blue vertical arrow ↓ pointing down with Q-value (MeV) in blue either to left or right; beta⁺ (β^+) decays are denoted with yellow arrow pointing upward to row above ↑

Alpha decays: indicated with orange arrows, proceed mostly from right to left at an angle with Q-value (MeV) shown in orange located on either side of the process arrow. ↖

Electron captures (e.c.): indicated by purple vertical arrow; Q-value (MeV) to left or right. ↑

Note: to reduce visual clutter in the network diagram, gamma emissions (converted to infrared photons by heavy e^{-*} electrons) are not shown; similarly, except where specifically listed because a given branch cross-section is significant, beta-delayed decays also generally not shown; BR means branching ratio if >1 decay path alternative

Color coded half-lives:

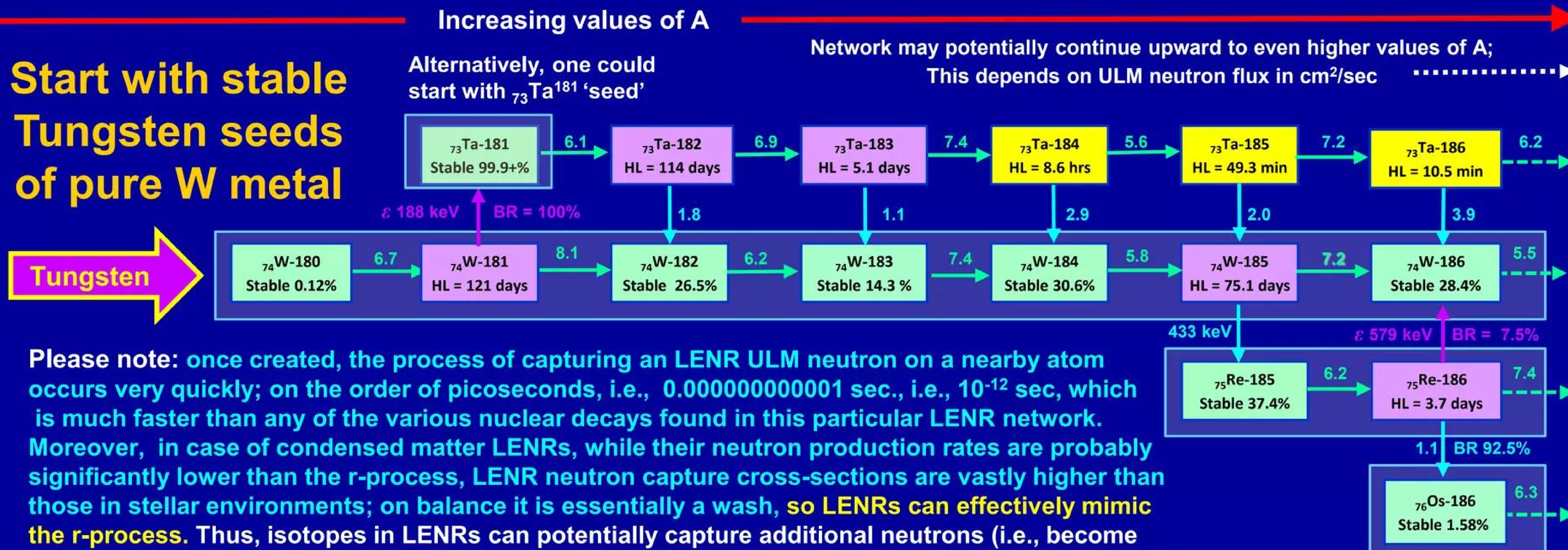
When known, half-lives shown as "HL = xx". Stable and quasi-stable isotopes (i.e., those with half-lives > or equal to 10^7 years) indicated by green boxes; isotopes with half-lives < 10^7 but > than or equal to 10^3 years indicated by light blue; those with half-lives < than 10^3 years but > or equal to 1 day are denoted by purplish boxes; half-lives of < 1 day in yellow; with regard to half-life, notation "? nm" means isotope has been verified by HL has not been measured

Measured natural terrestrial abundances for stable isotopes:

Indicated with % symbol; note that $_{83}Bi^{209}$ = 100% (essentially ~stable with half-life = 1.9×10^{19} yrs); $_{82}$Pb-205 ~stable with HL= 1.5×10^7 yrs;

Mitsubishi confirmed Nagaoka's 1925 experiments

Widom-Larsen theory Tungsten-seed LENR transmutation network

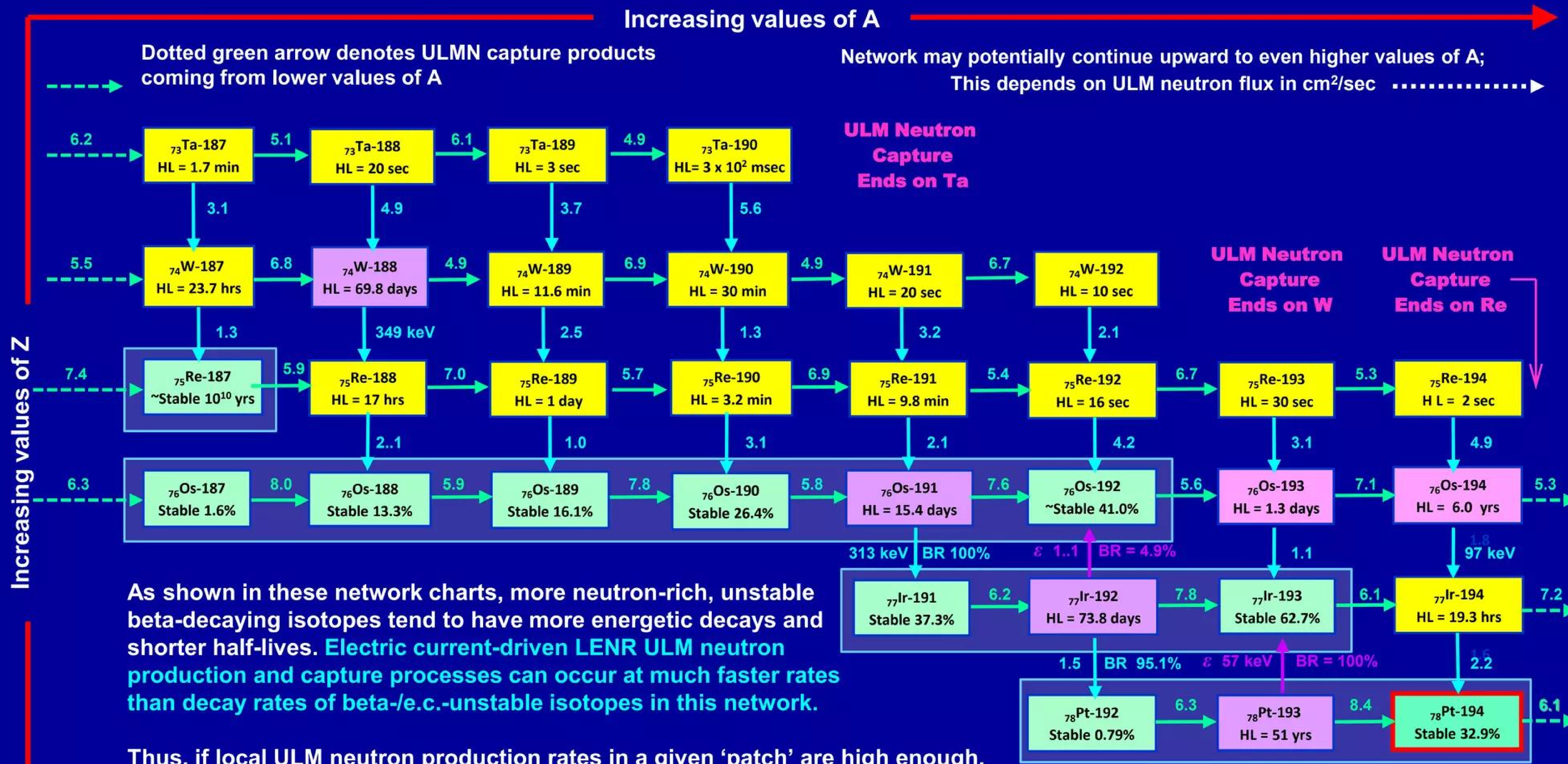


Please note: once created, the process of capturing an LENR ULM neutron on a nearby atom occurs very quickly; on the order of picoseconds, i.e., 0.000000000001 sec., i.e., 10^{-12} sec, which is much faster than any of the various nuclear decays found in this particular LENR network. Moreover, in case of condensed matter LENRs, while their neutron production rates are probably significantly lower than the r-process, LENR neutron capture cross-sections are vastly higher than those in stellar environments; on balance it is essentially a wash, so LENRs can effectively mimic the r-process. Thus, isotopes in LENRs can potentially capture additional neutrons (i.e., become more neutron-rich isotopes of the same element) before beta decay transmutes them into other higher-Z elements found in the Periodic Table. This is why super-hot astrophysical r-process can make heavier elements than the s-process (i.e., go beyond Bismuth): with much higher produced neutron fluxes, the r-process can successfully traverse and bridge key regions of very short-lived isotopes that are found in ultra-neutron-rich, high-Z reaches of vast nuclear isotopic landscape

It should also be noted that all of the many atoms located within a 3-D region of space that encompasses a given ULM neutron's spatially extended DeBroglie wave function (whose dimensions can range from 2 nm to 100 microns) will compete with each other to capture such neutrons. ULM neutron capture is thus a decidedly many-body scattering process, not few-body scattering such as that which characterizes capture of neutrons at thermal energies in condensed matter in which the DeBroglie wave function of a thermal neutron is on the order of ~ 2 Angstroms. This explains why vast majority of produced neutrons are captured locally and are only rarely detected at any energies during course of LENR experiments; it also clearly explains why human-lethal MeV-energy neutron fluxes are characteristically not produced in condensed matter LENR systems.

Mitsubishi confirmed Nagaoka's 1925 experiments

Widom-Larsen theory Tungsten-seed LENR transmutation network



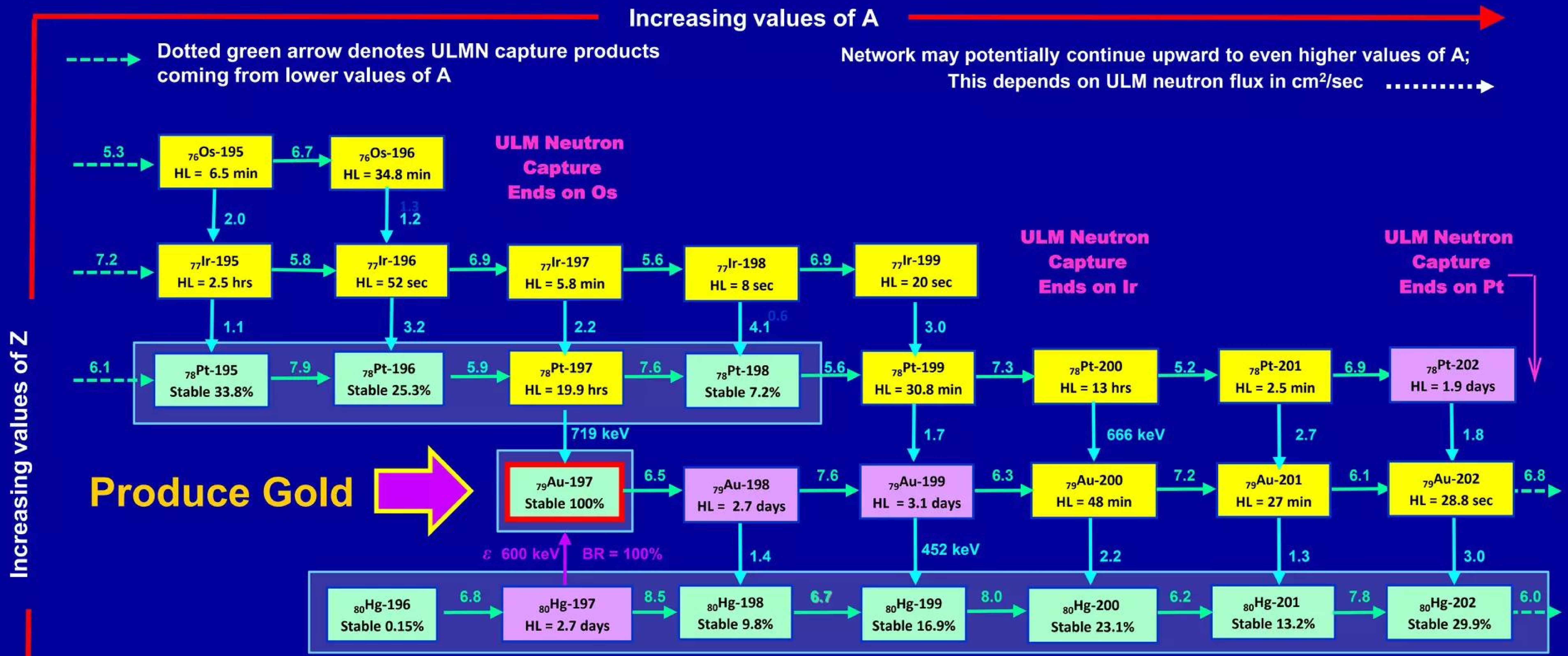
As shown in these network charts, more neutron-rich, unstable beta-decaying isotopes tend to have more energetic decays and shorter half-lives. Electric current-driven LENR ULM neutron production and capture processes can occur at much faster rates than decay rates of beta-/e.c.-unstable isotopes in this network.

Thus, if local ULM neutron production rates in a given 'patch' are high enough, large differences in rates of beta decay vs. neutron capture processes means that largish populations of unstable, very neutron-rich isotopes can accumulate locally during 300 nanosec lifetime of an LENR-active patch, prior to its being destroyed.

Produce Platinum

Mitsubishi confirmed Nagaoka's 1925 experiments

Widom-Larsen theory Tungsten-seed LENR transmutation network



Please note that: Q-value for neutron capture on a given beta-unstable isotope is often larger than the Q-value for the alternative β^- decay pathway, so in addition to being a faster process than beta decay it can also be energetically more favorable. This can also contribute to creating fleeting yet substantial local populations of short-lived, neutron-rich isotopes. There is indirect experimental evidence that such neutron-rich isotopes can be produced in complex ULM neutron-catalyzed LENR nucleosynthetic (transmutation) networks that set-up and operate during brief lifetime of an LENR-active patch; see Carbon-seed network on Slides # 11 - 12 and esp. on Slide #55 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewcarbon-seed-lenr-networkssept-3-2009

Mitsubishi confirmed Nagaoka's 1925 experiments

MHI reported Tungsten target results at 2012 Winter ANS meeting

Last American Nuclear Society meeting session on LENRs was 14 years ago

"Low Energy Neutron Reactions (LENRs): in theory, neutron-catalyzed LENR transmutations can produce Gold; already observed experimentally; may also occur naturally in the earth"

Lewis Larsen, Lattice Energy LLC [66 PowerPoint slides – not peer reviewed]
May 19, 2012 --- published by the company on SlideShare.net

http://www.slideshare.net/lewisglarsen/lattice-energy-llc-lenr-transmutationnetworks-can-produce-goldmay-19-2012

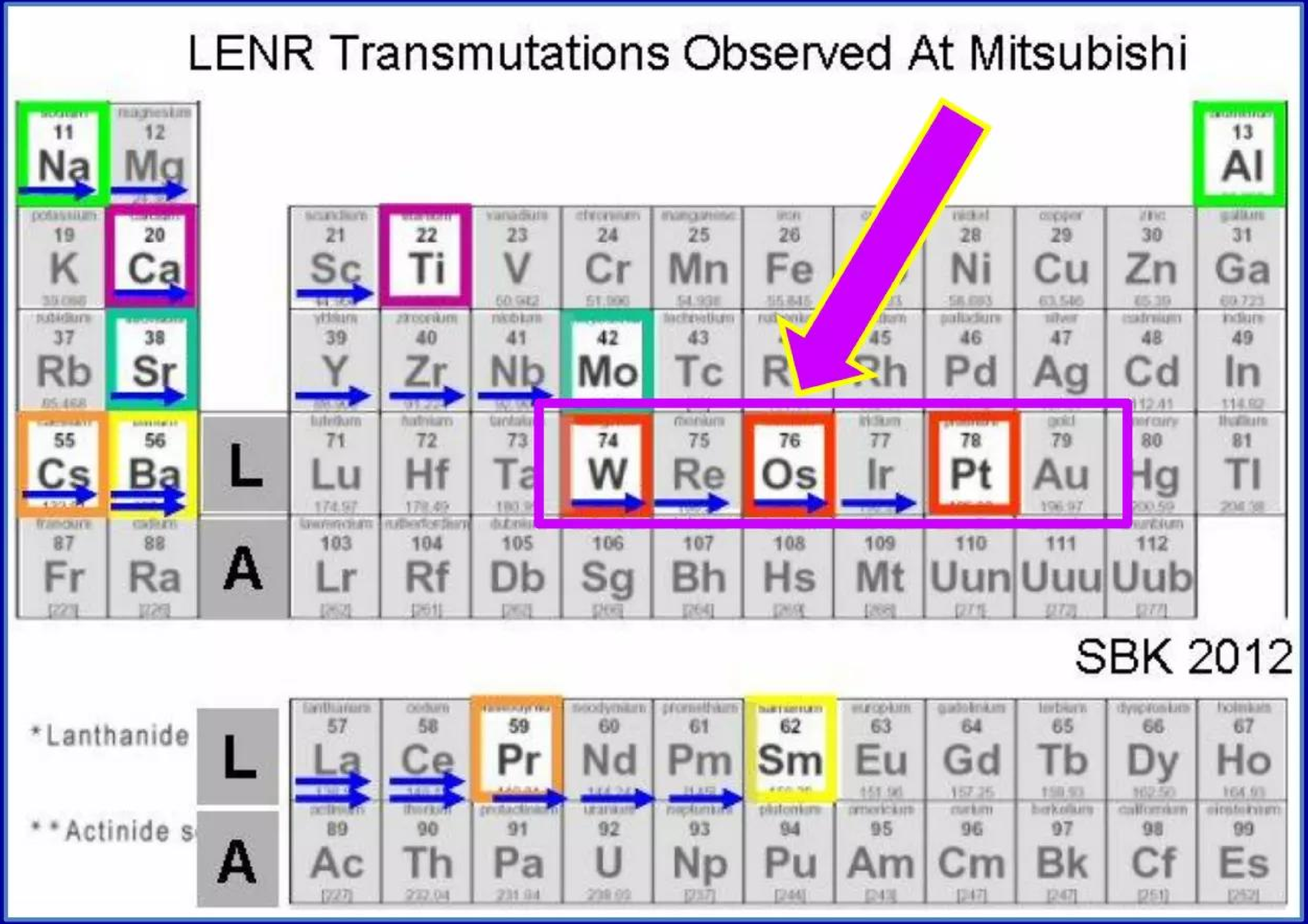
Selected documents concerning ANS Winter meeting LENR session held on November 14, 2012:

- ✓ Dec. 7, 2012: *New Energy Times* article by Steven Krivit article about this session (substantial part of its entire content is subscriber-only), titled, "Mitsubishi Reports Toyota Replication" http://news.newenergytimes.net/2012/12/06/mitsubishi-reports-toyota-replication/
- ✓ Dr. Yasuhiro Iwamura's 44-slide PowerPoint for presentation (free content - see Slides #26 - 29): http://newenergytimes.com/v2/conferences/2012/ANS2012W/2012Iwamura-ANS-LENR.pdf
- ✓ Iwamura's related 4-page paper published in *Transactions of the ANS* (free content - see page #3 just under Fig. 6 "SIMS Analysis for W Transmutation Expts"; note: cites 2006 W&L *EPJC* paper): http://newenergytimes.com/v2/conferences/2012/ANS2012W/2012Iwamura-ANS-LENR-Paper.pdf
- ✓ Online YouTube video for viewing Iwamura's live presentation at the ANS meeting (free content): http://youtu.be/VefCEaLAkRw (running time is ~43 minutes; Dr. Iwamura's English is excellent)

Mitsubishi confirmed Nagaoka's seminal 1925 experiments

MHI reported on Tungsten target results at 2012 Winter ANS meeting

Unable to reach Gold because MHI method's neutron fluxes are too low



Source of adapted graphic is *New Energy Times*:

http://news.newenergytimes.net/2012/12/06/mitsubishi-reports-toyota-replication/

Mitsubishi confirmed Nagaoka's 1925 experiments

MHI reported on Tungsten target results at 2012 Winter ANS meeting

Successfully confirmed vector of W-L theory's predicted pathway from W → Au

- ✓ Technical notes: permeation technique used by Iwamura *et al.* in experiments with Tungsten (W) targets produces only relatively small fluxes of ultra low momentum neutrons; their electroweak neutron production rate was therefore insufficient to drive the W-L LENR transmutation network all the way out to the stable Gold isotope during elapsed time of the experiments (only got as far as Platinum – Pt, which was observed)
- ✓ Please carefully examine data found in PowerPoint slides, related paper published in ANS *Transactions*, and video of Dr. Iwamura's Nov. 14, 2012, ANS meeting presentation
- ✓ While Mitsubishi's carefully conducted LENR experiments did not reach Gold, they did observe key intermediate nucleosynthetic products, namely Osmium and Platinum
- ✓ Since Nagaoka's experiments had vastly higher levels of input energy in the form of electric currents, per W-L theory they would be expected to produce higher neutron fluxes and progress further into the LENR network: in fact, Nagaoka did reach Gold
- ✓ Quoting directly from *New Energy Times* subscriber-only content concerning 2012 Winter ANS meeting, *"A member of the audience asked Iwamura whether other Japanese companies besides Toyota and Mitsubishi are working on LENR. Iwamura said yes but they were not disclosing it."* These companies are serious LENR players

Additional reading for the technically inclined

Stable target seed elements

+ ULM neutrons

Release nuclear binding energy

Gamma conversion to IR + clean decay processes

Other heavier stable elements in Periodic Table

Welcome to the New World of the future of energy

Additional reading for the technically inclined

LENR nucleosynthesis occurs in Nature as well as the laboratory

Red giant stars, supernovae, fission reactors, and weapons are unnecessary

LENRs occur naturally at relatively low rates in amazing variety of different types of systems:

- ✓ **Catalytic converters of cars and trucks during normal vehicular operation**
  http://www.slideshare.net/lewisglarsen/lattice-energy-llc-len-rs-in-catalytic-convertersjune-25-2010

- ✓ **Ordinary atmospheric lightning discharges**
  http://www.slideshare.net/lewisglarsen/audio-larsenelectroweak-neutron-production-and-capture-in-lightning-dischargesans-san-diego-nov-14-2012

- ✓ **Industrial coking ovens during normal operation of pyrolysis processes (Slides #46 - 48)**
  http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewpahs-and-lenrsnov-25-2009

- ✓ **"Water trees" that can form spontaneously in XLPE electric power cables (Slides #49 - 54)**
  http://www.slideshare.net/lewisglarsen/cfakepathlattice-energy-llc-len-rs-in-liion-battery-firesjuly-16-2010

- ✓ **Compact fluorescent lights in which LENRs could potentially be occurring at low rates**
  http://www.slideshare.net/lewisglarsen/lattice-energy-llcare-lenrs-occurring-in-compact-fluorescent-lightsmarch-7-2013

Additional reading for the technically inclined

Detailed discussion and analysis of recent U.S. patent application by Mitsubishi :

"Analysis and comments: patent application: US 2012/0269309 A1 by Mitsubishi Heavy Industries, Ltd."
Lewis Larsen, Lattice Energy LLC, July 28, 2013 [8.5 x 11 - 51 pages]

http://www.slideshare.net/lewisglarsen/lattice-energy-llcwidomlarsen-theory-explains-data-presented-in-new-mitsubishi-us-patent-applicationjuly-28-2013

Lattice document concerning LENR-based power generation systems vs. fission and fusion:

"Truly green nuclear energy exists – an overview for everybody: no deadly gammas … no energetic neutrons … and no radioactive waste"
L. Larsen, Lattice Energy LLC, v. 4 updated and revised through June 28, 2013 [109 slides]

http://www.slideshare.net/lewisglarsen/powering-the-world-to-a-green-lenr-future-lattice-energy-llcapril-11-2013

Index to large collection of documents re LENR theory, experimental data, and the technology:

"Index to key concepts and documents" v. #14
L. Larsen, Lattice Energy LLC, May 28, 2013 [88 slides] Updated and revised through September 12, 2013

http://www.slideshare.net/lewisglarsen/lattice-energy-llc-index-to-documents-re-widomlarsen-theory-of-lenrsmay-28-2013

A tribute to scientists and companies of Japan

Important contributions to LENRs since 1925

A tribute to scientists and companies of Japan

Important contributions to LENRs since 1925

Lattice would like to pay tribute to the many fine Japanese scientists and companies who have made important contributions to our understanding of LENRs over the past 88 years. Unfortunately, there is only enough room here to mention barely a handful of them. Nonetheless, please rest assured that all of them will be long-remembered by those of us who have worked in this exciting new field of science.

Prof. Hantaro Nagaoka (*Nature*, 1925) was the first-ever to demonstrate that Tungsten can be transmuted into Gold with high-current electric discharges in oil. While no one repeated his seminal experiments during that era, the passage of time has not diminished the great importance or relevance of his still-astounding experimental discoveries of 88 years ago.

Minoru Toyoda bravely supported LENR R&D conducted in Nice, France at the height of the acrimonious LENR controversy back in the 1990s.

Toyota and Mitsubishi have both reported many important experimental results dating back to 1989; Mitsubishi pioneered the development of the permeation method which resulted in the publication of a seminal *JJAP* paper in 2002. Toyota has just confirmed their results in a *JJAP* paper published 11 years later.

Tadahiko Mizuno has made many important experimental contributions over the years, including brilliant experiments with Phenanthrene in 2008 which demonstrated that W-L neutron production could be triggered on aromatic benzene rings.

On the theory side: in a book published in 1997, Mizuno informally speculated without using mathematics that the e + p weak interaction created neutrons during LENR experiments which explained the transmutation products that he had observed . In 1998, Iwamura *et al.* published their EINR theory of LENRs which is really a phenomenological version of the neutron-based Widom-Larsen theory without any detailed physics or mathematics. The Widom-Larsen theory provides detailed physics of LENRs in a rigorous mathematical form.

Final quote

H.E. Sheikh Ahmed Zaki Yamani

"The Stone Age came to an end, but not for a lack of stones, and the oil age will end, but not for a lack of oil."

H.E. Sheikh Ahmed Zaki Yamani
أحمد زكي يماني formerly
Oil Minister of Saudi Arabia

Stated during a media interview (2000)