Hidden history of 1989 “cold fusion” debacle revealed

Pons & Fleischmann excess heat data was likely measured correctly

Also correct in their idea that heating process was nuclear - it just wasn’t fusion

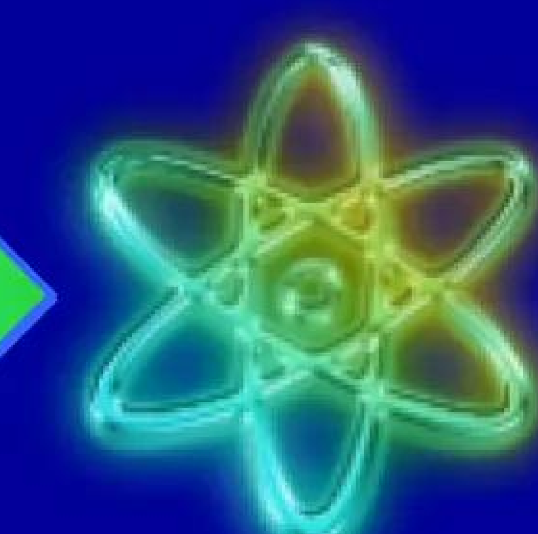
Synopsis of the new popular science book

“Fusion Fiasco” by Steven B. Krivit

By late October 1989 Dr. Edward Teller, ‘father’ of first U.S. Hydrogen bomb, thought that Pons & Fleischmann had discovered a little-understood nuclear process that could operate in ordinary electrochemical cells. Bizarre absence of deadly hard radiation indicated to him that P&F’s puzzling results probably weren’t caused by a fusion process. After seeing all the ERAB panel’s data, he further speculated that the underlying process was very likely nuclear and possibly catalyzed by “neutral particle of small mass and marginal stability” that was somewhat akin to a neutron. **Krivit reveals how Teller’s prescient insights were ignored by DOE ERAB panel and effectively buried for 27 years.**

Lewis Larsen
President and CEO, Lattice Energy LLC
December 8, 2016

Fission/fusion → evolution of nuclear technology → LENRs



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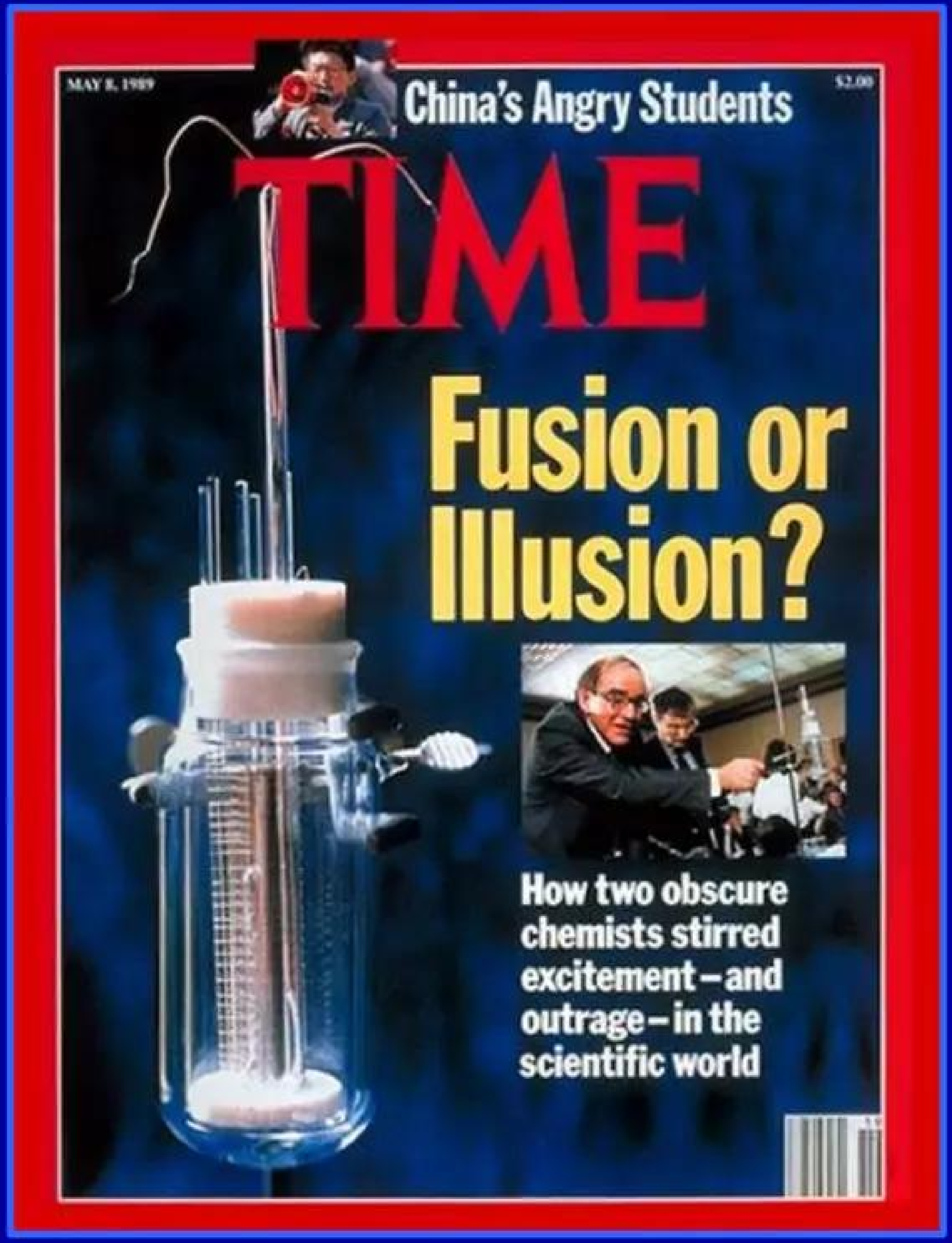
Pons & Fleischmann's results inconsistent with fusion

Key issue along with irreproducibility doomed Pons & Fleischmann

By late 1990 results discredited and presumed to arise from experimental error

- ✓ Supposed D+D fusion in electrochemical cells, as envisioned by Pons & Fleischmann, was really just an erroneous hypothesis unsupported by the data
- ✓ However, 27 years later we now know that while P&F's theorized room temperature "cold fusion" mechanism was wrong, "Fusion Fiasco" shows that their excess heat measurements were likely correct and they may have produced Helium-4
- ✓ Thanks to Widom-Larsen theory of LENRs, we can now understand and explain all P&F's excess heat measurements as well as the baffling absence of deadly energetic neutron and gamma radiation
- ✓ In 1989, other scientists used mass spectroscopy to look for isotopic shifts as evidence of nuclear transmutations in P&F-type cells and observed it in post-experiment analysis of cathodes. Krivit shows how this data was lost in the controversy



Time Magazine May 8, 1989

"Fusion Fiasco"

History of Pons & Fleischmann's 1989 "cold fusion" debacle is rewritten

https://www.amazon.com/dp/0976054523

Second book in the series "Explorations in Nuclear Research"

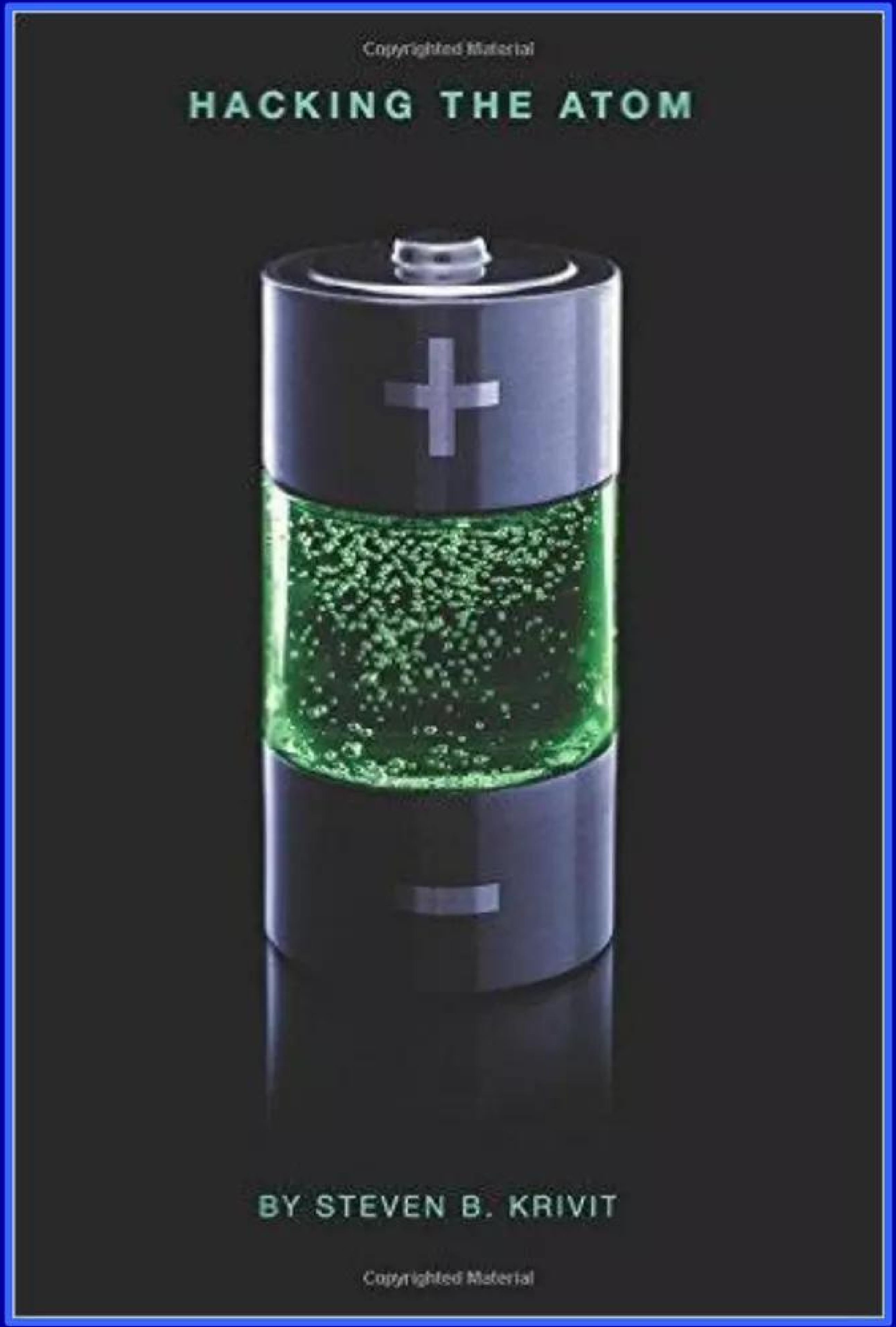
"Fusion Fiasco"
"Explorations in nuclear research" (Volume 2)
Steven B. Krivit
Michael J. Ravnitzky, ed.
Cynthia Goldstein, ed.
Mat Nieuwenhoven, ed.
Pacific Oaks Press, San Rafael, CA
November 11, 2016 (531 pages)
Sold on Amazon.com
Paperback US$16.00; hardcover US$48.00
Electronic versions to follow

“Hacking the Atom”

Overview of Widom-Larsen theory of LENRs and key experimental data

https://www.amazon.com/dp/0996886451

First book in the series “Explorations in Nuclear Research”



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Contents

Comparison of LENRs to fission and fusion

Fission, fusion, and LENRs all involve controlled release of nuclear binding energy (heat) for power generation: no CO_2 emissions; scale of energy release is MeVs (nuclear regime) > 1,000,000x energy density of chemical energy power sources

Heavy element fission: involves shattering heavy nuclei to release stored nuclear binding energy; requires massive shielding and containment structures to handle radiation; major radioactive waste clean-up issues and costs; limited 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 radioisotopes) + energetic gamma radiation + energetic neutron radiation + heat

Fusion of light nuclei: involves smashing light nuclei together to release stored nuclear binding energy; present multi-billion $ development efforts (e.g., ITER, NIF, other Tokamaks) focusing mainly on D+T fusion reaction; requires massive shielding/containment structures to handle 14 MeV neutron radiation; minor radioactive waste clean-up $ costs vs. fission

Two key sources of fuel: Deuterium and Tritium (both are heavy isotopes of Hydrogen)

Most likely to be developed commercial fusion reaction involves the following:

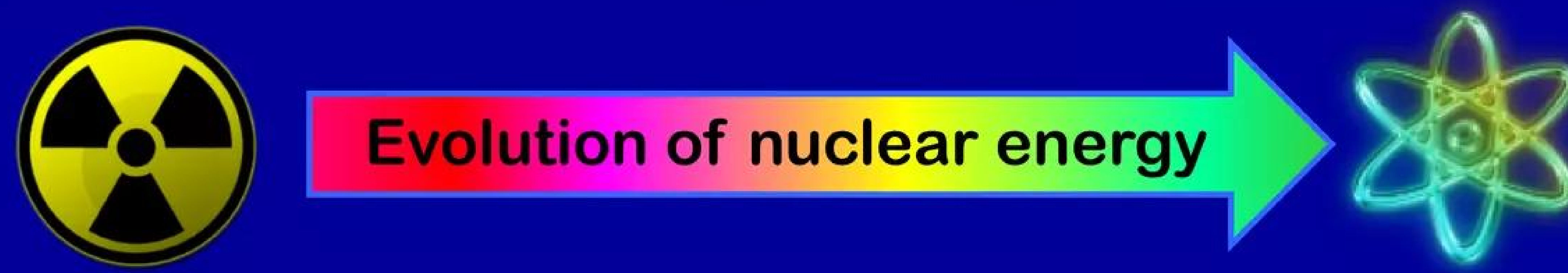
D + T → He-4 (helium) + neutron + heat (total energy yield 17.6 MeV; ~14.1 MeV in neutron)

Ultralow energy neutron reactions (LENRs): distinguishing feature is neutron production via electroweak reaction; neutron capture on fuel + gamma conversion to IR + decays [β^-, α] releases nuclear binding energy; early-stage technology; no emission of energetic neutron or gamma radiation and no long-lived radioactive waste products; LENR systems would not require massive, expensive radiation shielding or containment structures → much lower $$$ cost; many possible fuels --- any element/isotope that can capture LENR neutrons; involves neutron-catalyzed transmutation of fuels into heavier stable elements; process creates heat

Man’s 70-year quest for greener nuclear energy sources

Ultralow energy neutron reactions (LENRs) are neither fission nor fusion

Fission and fusion



Safe green LENRs

- ✓ Beginning with Hans Bethe’s landmark paper published back in in 1939, the Holy Grail and longstanding dream of nuclear science has been to commercialize the same clean (compared to fission) fusion reactions that power stars and our Sun
- ✓ Less technically difficult nuclear fission technology was first utilized in weapons and later deployed in commercial nuclear power reactors. It has been fraught with safety, cost, and serious nuclear proliferation issues that are well-known
- ✓ Both fission and fusion rely primarily on the strong interaction and are triggered by energetic few-body nuclear reactions. Accordingly, both types of few-body processes produce deadly hard radiation and long-lived radioactive isotopes
- ✓ Up until advent of many-body collective effects Widom-Larsen theory in 2005, the weak interaction was thought to be useless for large-scale power generation
- ✓ Thanks to Widom-Larsen theory, we now know that radiation-free ‘green’ LENRs based on the weak interaction are enabled by many-body collective physics in condensed matter and can occur at substantial rates under the right conditions
- ✓ We are thus facing a paradigm shift in long term evolution of nuclear technology

Condensed matter ultralow energy neutron reactions

Radiation-free LENRs transmute stable elements to other stable elements

Laura 13

No deadly MeV-energy gamma radiation

No dangerous energetic neutron radiation

Insignificant production of radioactive waste

Vastly higher energies vs. chemical processes

Revolutionary, no CO_2 , and environmentally green

Is fully explained by physics of Widom-Larsen theory

Image credit: co-author Domenico Pacifici
From: “Nanoscale plasmonic interferometers for multispectral, high-throughput biochemical sensing”
J. Feng et al., *Nano Letters* pp. 602 - 609 (2012)

Electroweak reaction in Widom-Larsen theory is simple

Protons or deuterons react directly with electrons to make neutrons

Need input energy source such as electricity to drive LENR neutron production

electrons + protons (Hydrogen) → neutrons + neutrinos (benign photons, fly into space)

Require source(s) of input energy

Input energy creates electric fields > 2.5 x10^{11} V/m

Collective many-body quantum effects: many electrons each transfer little bits of energy to a much smaller number of electrons also bathed in the very same extremely high local electric field

Many-body collective electroweak neutron production

Heavy-mass $e^{-}*$ electrons react directly with protons

Quantum electrodynamics (QED): smaller number of electrons that absorb energy directly from local electric field will increase their effective masses ($m = E/c^2$) above key thresholds β_0 where they can react directly with a proton (or deuteron) → neutron and neutrino

$$\mathrm{Energy}_{E\text{-field}} + e^{-}_{sp} \rightarrow e^{-*}_{sp} + p^{+} \rightarrow n^{0} + v_{e}$$

v_e neutrinos: ghostly unreactive photons that fly-off into space; n^0 neutrons capture on nearby atoms

Radiation-free LENR transmutation

Neutrons + capture targets → heavier elements + decay products

Neutrons induce nuclear transmutations that release enormous amounts of clean, CO_2-free heat

Widom-Larsen theory explains LENRs in condensed matter

Collective electroweak neutron production, capture, and nuclear decays

Nuclear-strength, micron-scale local electric fields drive LENR neutron production

Many-body collective production of neutrons, neutrinos, and other particles:

Collective many-body processes require external input energy

$$e^{-*} + p^{+} \rightarrow n + \nu_e$$ Electric fields dominate

$$e^{-} + p^{+} \rightarrow lepton + X$$ Magnetic fields dominate

Electroweak particle reactions produce neutrons (n) and neutrinos (ν_e)

Transmutation of elements and nucleosynthesis in condensed matter:

Neutron capture-driven LENR transmutation reactions

$$n + (Z, A) \rightarrow (Z, A+1)$$ Neutron capture

$$(Z, A+1) \rightarrow (Z + 1, A+1) + e_{\beta}^{-} + \bar{\nu}_e$$ Beta-minus decay

Unstable neutron-rich products of neutron captures will undergo beta$^-$ decay

Create heavier stable isotopes or heavier elements along rows of Periodic Table

Ultralow energy neutrons created in electrochemical cells

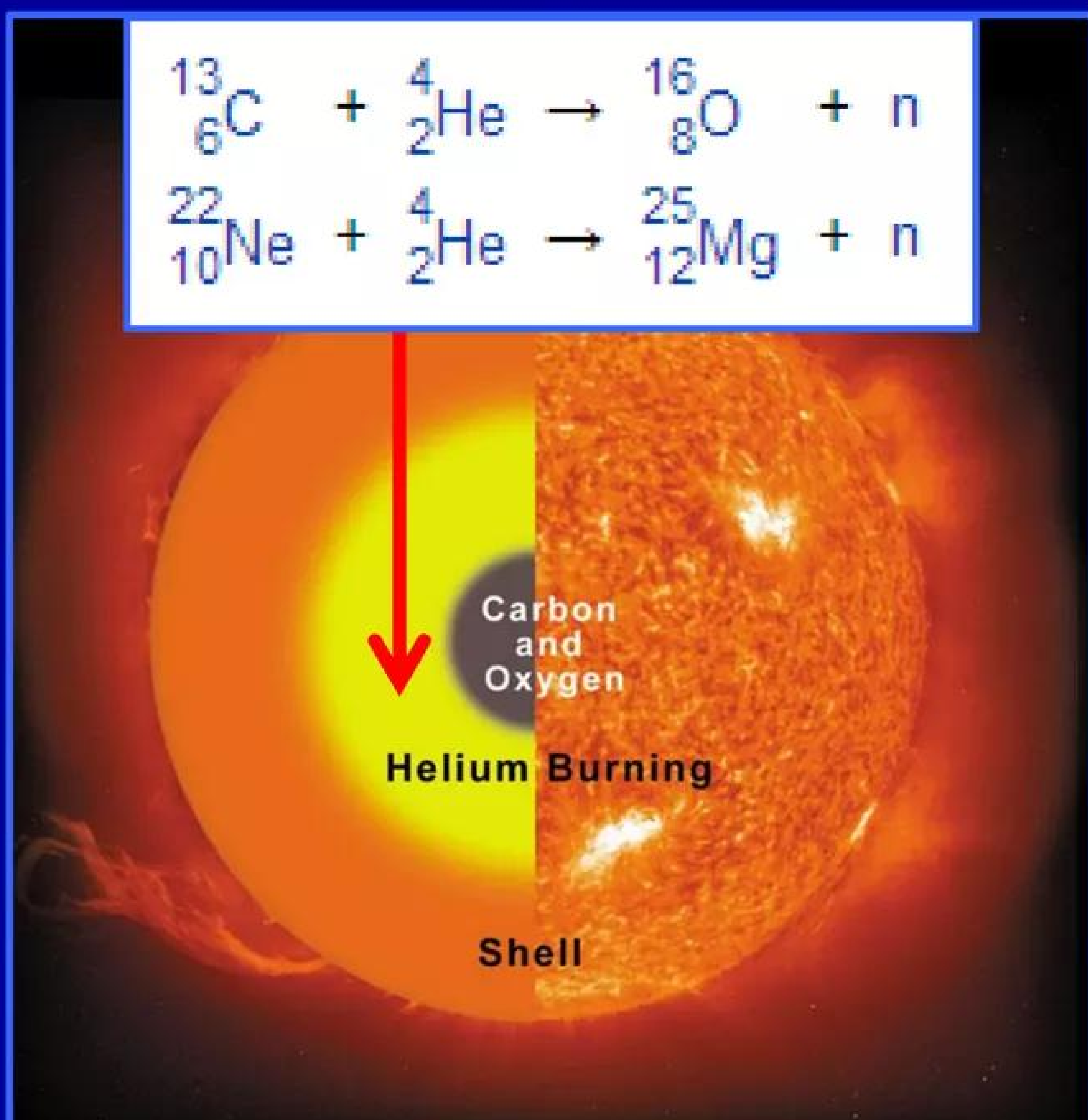
Production with weak $e + p$ reaction creates safe low energy neutrons

Ultralow energy LENR neutrons are captured locally and will not escape reactors

All these nuclear fusion and LENR reactions below create neutrons (n):

Fusion reactions in Red Giant star

Energetic MeV-energy neutrons



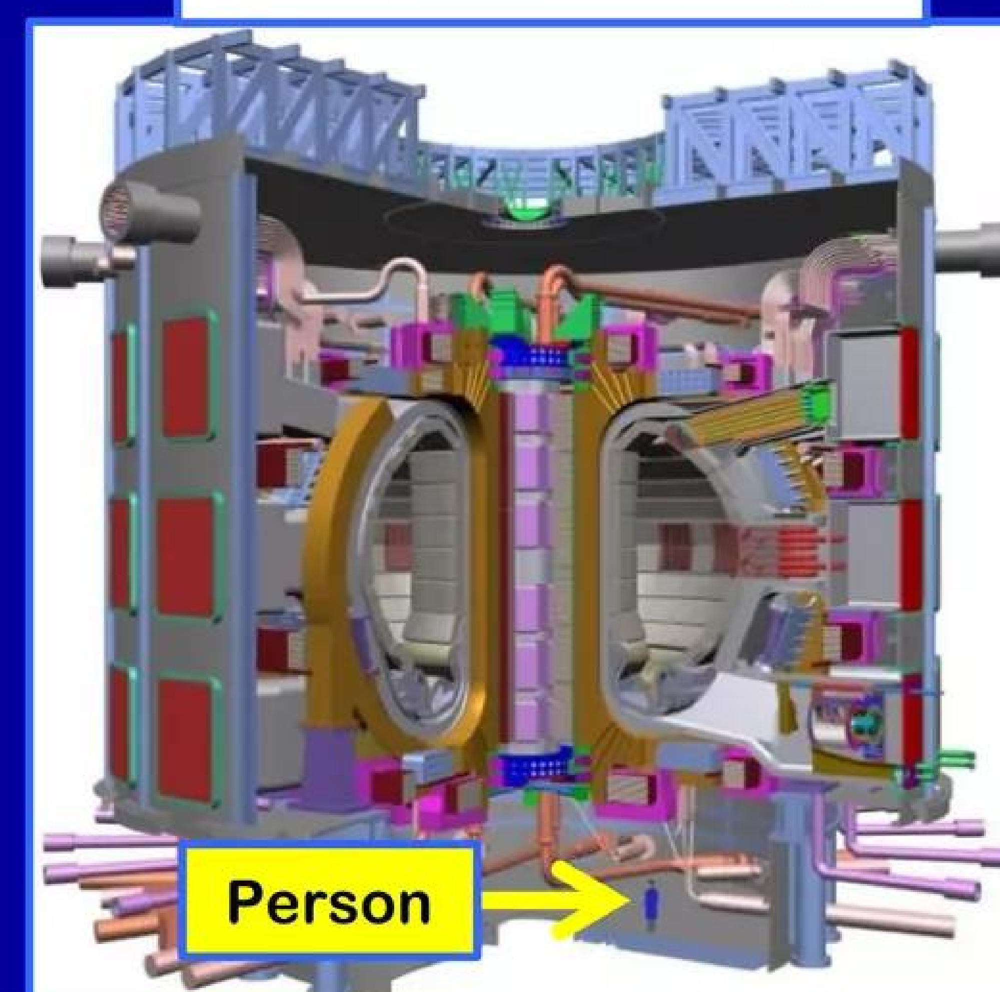
Length-scale: millions of miles

Temperatures: millions of degrees

ITER: D+T fusion reactor

Deadly energetic 14 MeV neutrons

$$^{2}_{1}D + ^{3}_{1}T \rightarrow ^{4}_{2}He + ^{1}_{0}n$$



Length-scale: hundreds of feet

Temperatures: millions of degrees

LENR device

These are bio-safe

$$e + p \rightarrow \nu_e + n$$

Length-scale: inches

Temperatures: only thousands of degrees in microscopic regions

Widom-Larsen theory explains absence of gamma radiation

Unreacted heavy-mass electrons convert gammas directly into heat (IR)

- ✓ Intense heat produced by LENRs in microscopic active sites is from:
  - Large population of unreacted, collectively oscillating heavy-mass SP or π electrons that directly convert dangerous gamma photons created by nearby neutron captures and nuclear decay processes directly into benign infrared photons (IR - heat). IR produced by direct gamma conversion is absorbed by and heats-up local matter
  - See Lattice's fundamental U.S. patent involving this novel process: US# 7,893,414 B2 that was granted and issued on February 22, 2011
  - Energetic charged particles (e.g., alphas, betas, protons, deuterons, tritons) impacting materials in the nearby environment; heat-up local materials by transferring kinetic energy from such charged particles
- ✓ Note: emitted neutrino photons do not contribute to locally generated heat; bleed-off some excess nuclear energy into deep space by emission of benign form of energetic electromagnetic radiation
- ✓ Heating is sufficient to flash-boil refractory metals and form craters

Widom-Larsen provides description for LENR-active sites

Size of these active sites ranges from 2 nanometers up to ~100+ microns

Active sites have limited lifetimes before being destroyed by fast nuclear heating

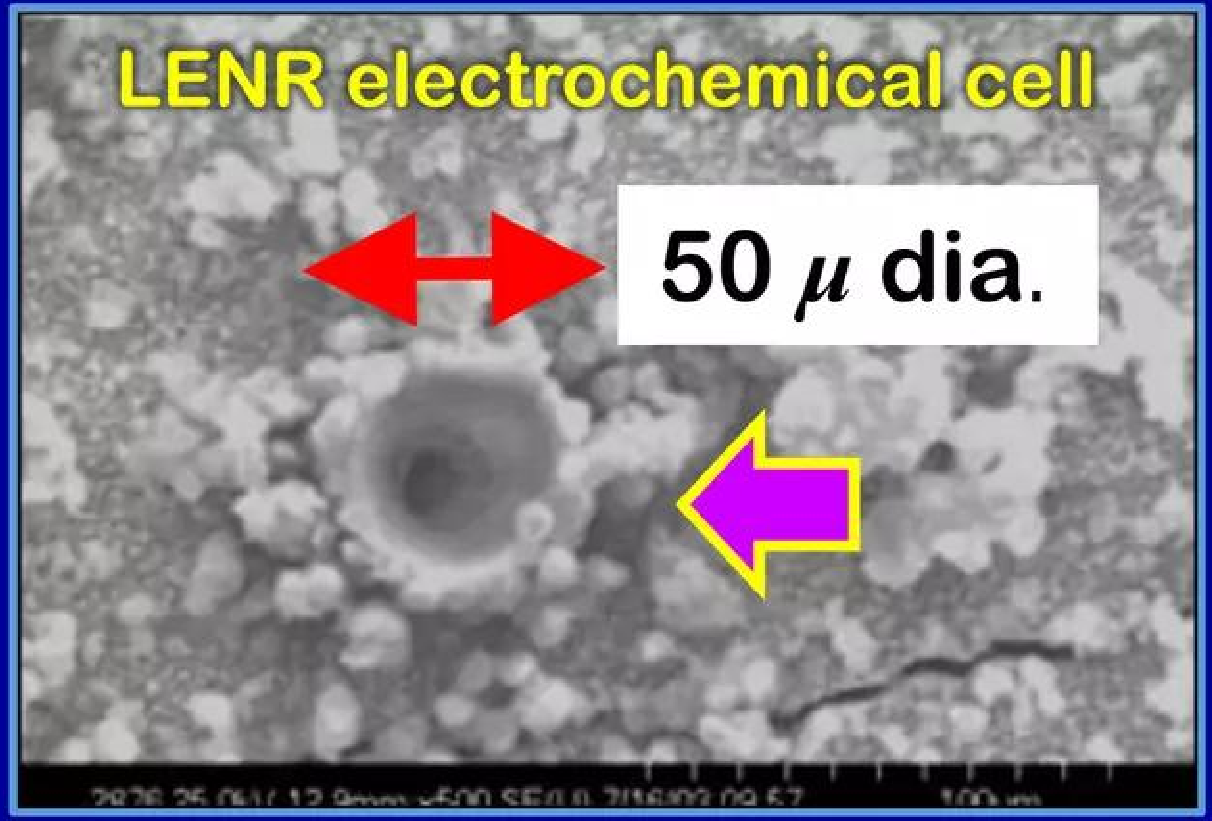
- ✓ Per Widom-Larsen theory LENRs occur in localized micron-scale LENR-active sites on ~planar surfaces: at certain types of interfaces\; or curved surfaces of various shaped nanoparticles
- ✓ Tiny LENR-active sites live for less than ~300 - 400 nanoseconds before being destroyed by intense heat; local peak temps range from 4,000 - 6,000^{o} C; LENR-active sites spontaneously reform under right conditions in well-engineered LENR thermal devices
- ✓ Microscopic 100-micron LENR hotspot can release as much as several Watts of heat in < 400 nanoseconds Create crater-like features on surfaces that are visible in SEM images; provides evidence for flash-boiling of both precious & refractory metals
- ✓ Peak local LENR power density in microscopic LENR-active sites can hit > 1.0 x 10^{21} Joules/sec·m^3 during brief lifetimes
- ✓ Control macroscopic-scale temperatures in LENR systems by tightly regulating total input energy and/or total area/volumetric densities of LENR-active sites present in the reaction chambers

Widom-Larsen provides description of LENR active sites

Size of these active sites ranges from 2 nanometers up to ~100+ microns

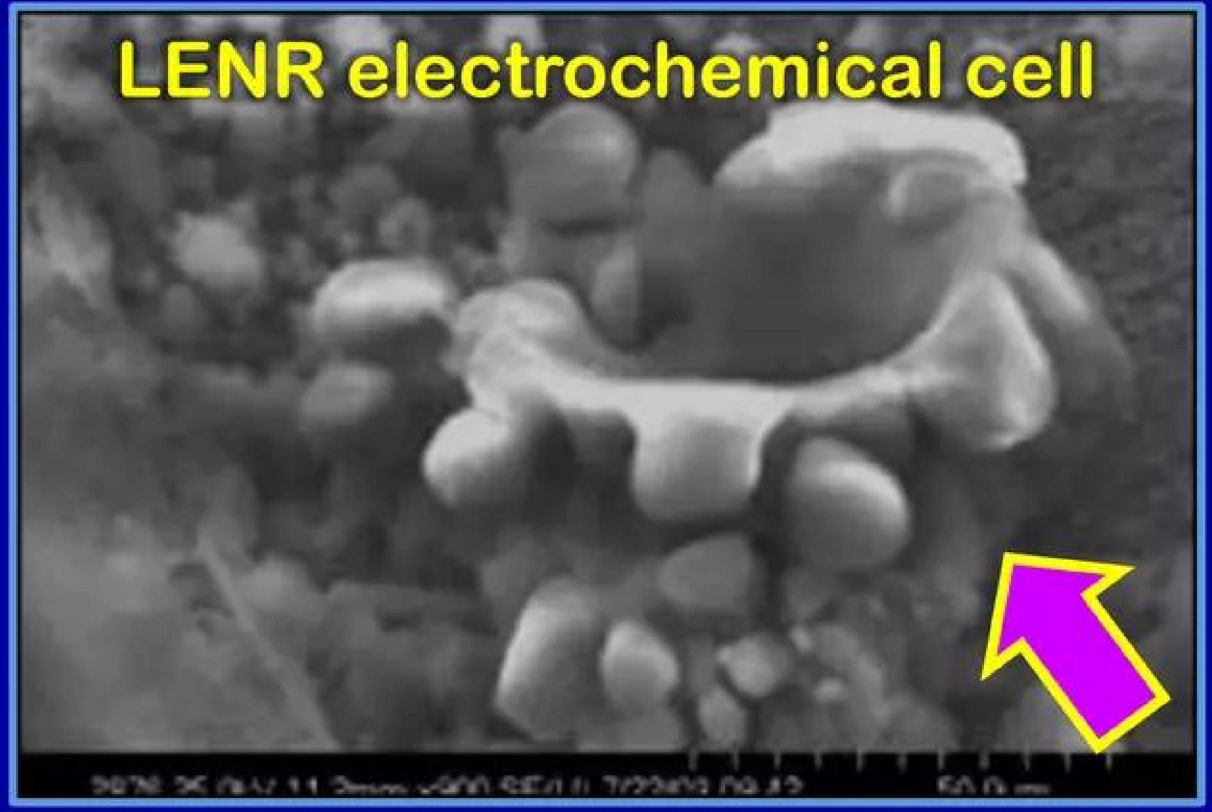
Active sites have short lifetimes before being destroyed by rapid nuclear heating

50 μ LENR active site crater in Pd cathode



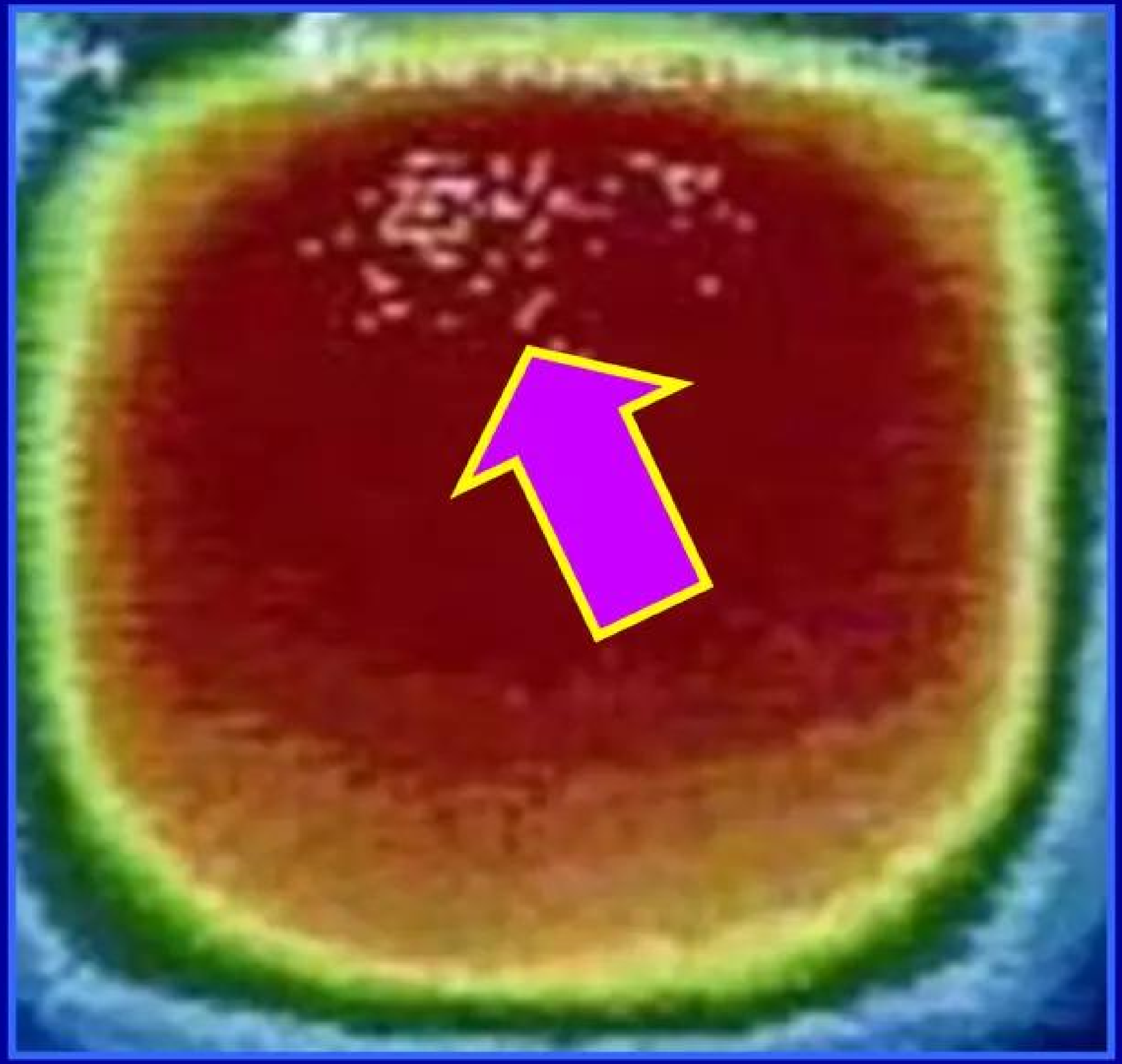
Credit: P. Boss, U.S. Navy SPAWAR

LENR active site crater on Pd cathode



Credit: P. Boss, U.S. Navy SPAWAR

Infrared video of LENR hotspots that form spontaneously on Pd cathode surfaces in aqueous electrochemical cells



http://www.youtube.com/watch?v=OUVmOQXBS68

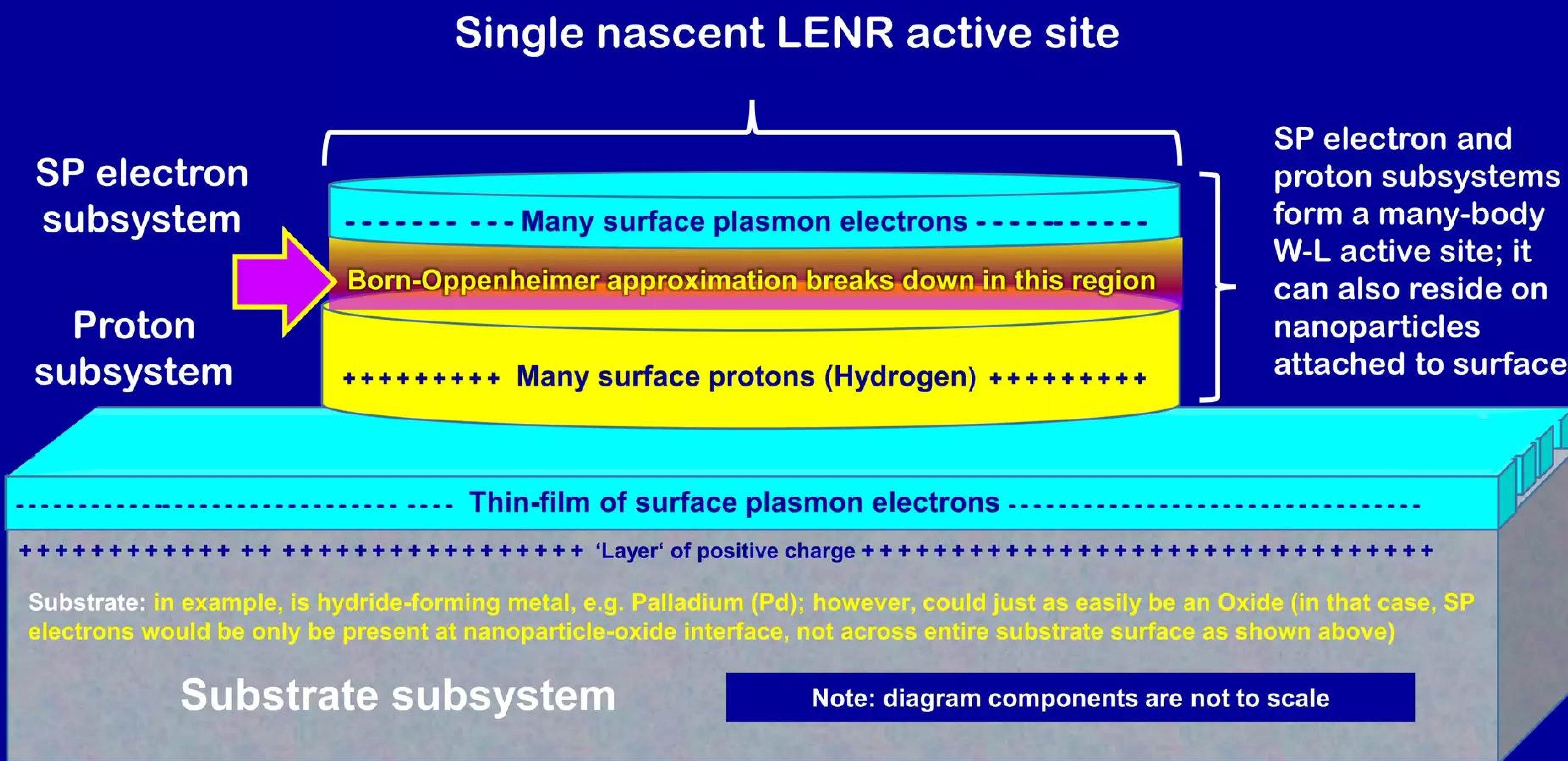
Credit: P. Boss, U.S. Navy SPAWAR (1994)

W-L concept of a microscopic LENR-active surface site

Comprised of many-body patches of protons and electrons on surface

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

Diameters of many-body active sites randomly range from several *nm* up to ~ 100^{+} microns



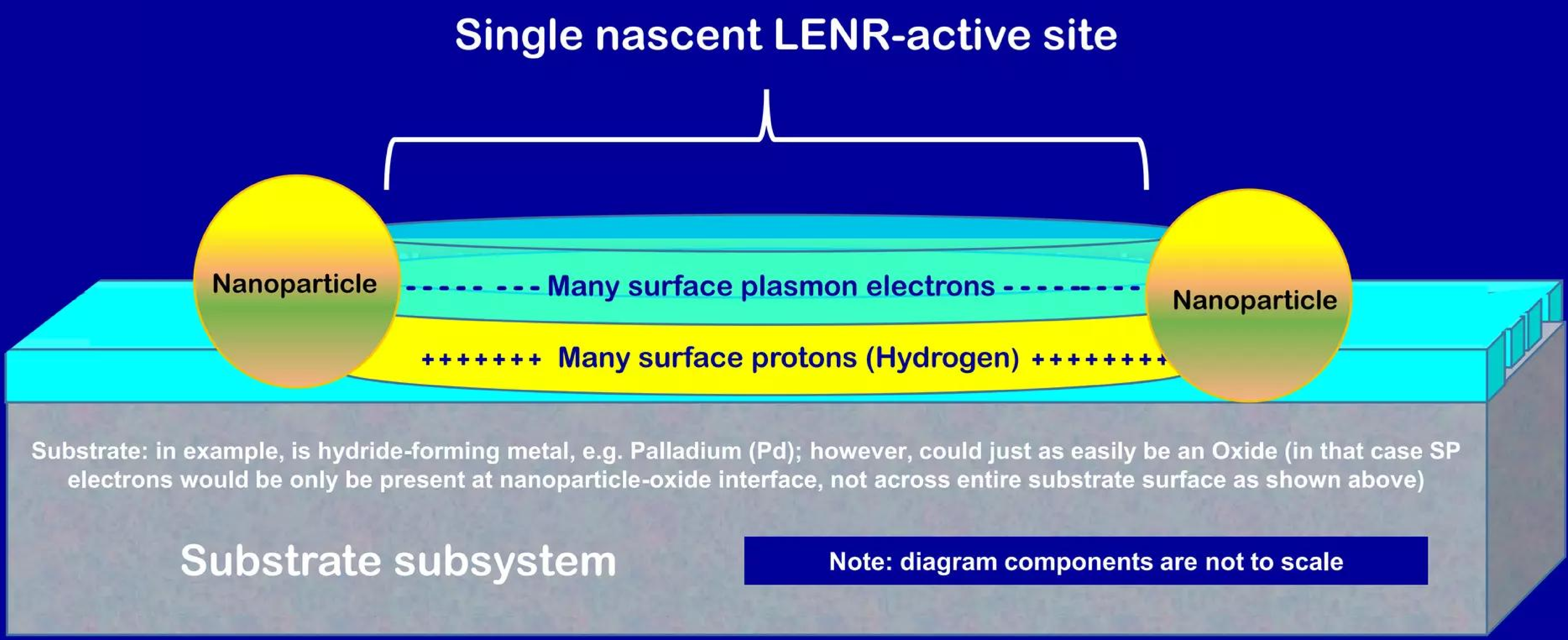
Input energy creates high electric fields in LENR active sites

Born-Oppenheimer breakdown enables nuclear-strength local E-field

Huge electric field increase effective masses of some patch SP electrons

Correct input energies create huge local E-fields > 2.5 x 10^{11} V/m between adjacent nanoparticles

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



LENRs occur in microscopic active sites found on surfaces

Many-body collections of protons and electrons form spontaneously

Ultralow energy neutrons produced & captured close to LENR-active sites

After being produced, neutrons capture on targets in/around active sites

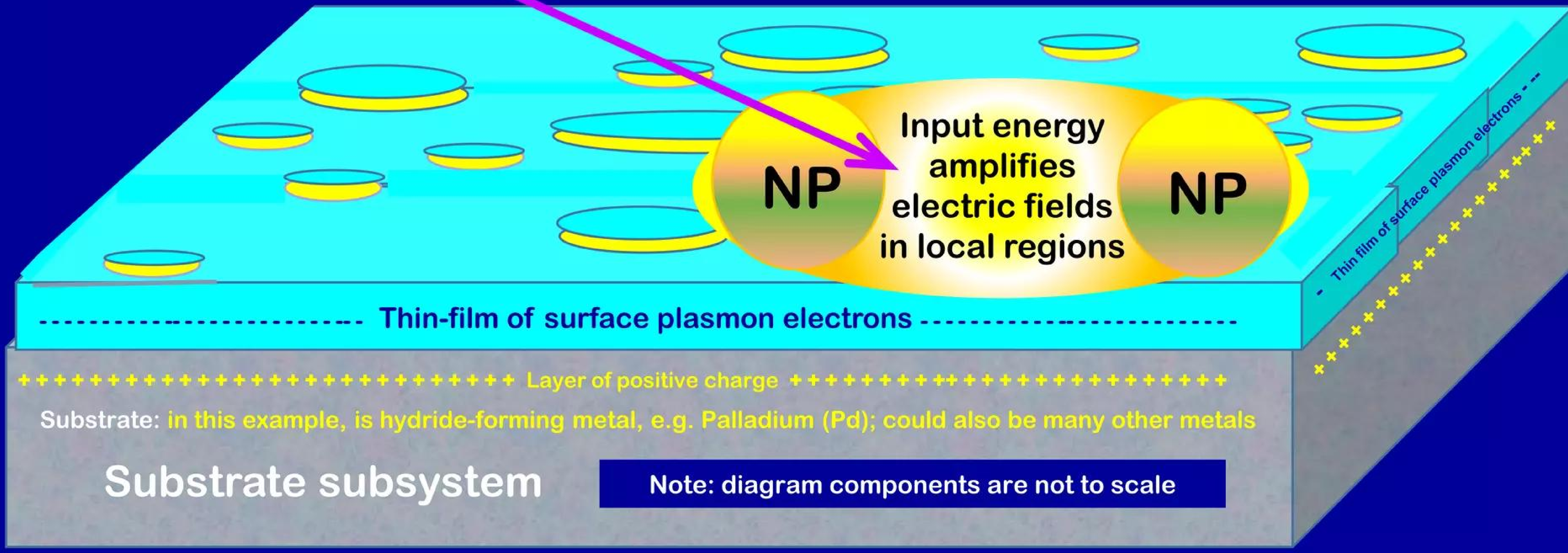
Intense heating in LENR-active sites will form μ-scale event craters on substrate surfaces

$n + (Z, A) \rightarrow (Z, A+1)$ [neutrons capture on nearby target atoms]

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

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

= Metallic nanoparticle (NP)

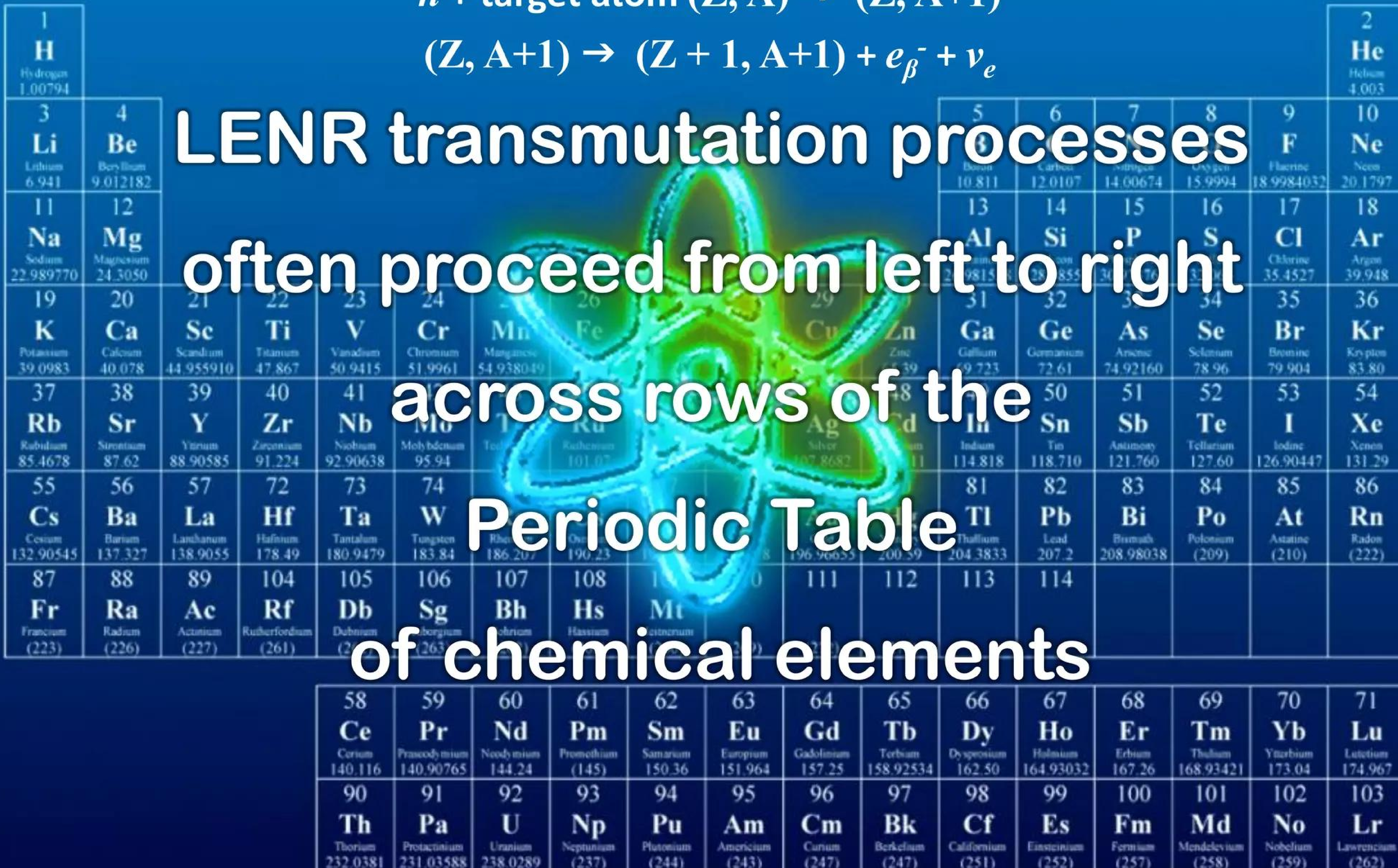


Neutrons are charge-neutral; atoms readily absorb them

Capture of neutrons by atoms will transmute them into other isotopes

$$n + \text{target atom } (Z, A) \rightarrow (Z, A+1)$$

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



LENR transmutation processes often proceed from left to right across rows of the Periodic Table of chemical elements

LENRs can be triggered in electrochemical cell experiments

Feature	Electrochemical LENRs
Result of process	Irreversible; transmutes elements
Basic reactions that produce neutrons	$e^- + p^+ \rightarrow 1\ n^0 + \nu_e$ $e^- + d^+ \rightarrow 2\ n^0 + \nu_e$
Proton sources	Aqueous: H_2O, D_2O
Electrons	Surface plasmons (metal hydrides) or π electrons on Carbon aromatic rings
Anode materials	Platinum Pt, Tungsten W, Carbon C
Cathode materials	Pd, Ni, Ti, W, other metal hydrides, C
Electrolytes	H_2O, D_2O (Hydrogen bubbles will form on cathode surfaces)
Electrolyte salts	LiOD, LiOH, Li_2SO_4, H_2SO_4, K_2CO_3
Operating voltages	Vast range of experimental values: 2 V all the way to > 350 V per cell
Local electric field strength in active sites	Briefly > 2.5×10^{11} V/m to produce LENR ultralow energy neutrons
Cell operating temperature range	Laboratory experiments ≤ 100° C Microscopic LENR active site hotspots briefly hit 4,000 - 6,000° C Sites generate excess heat

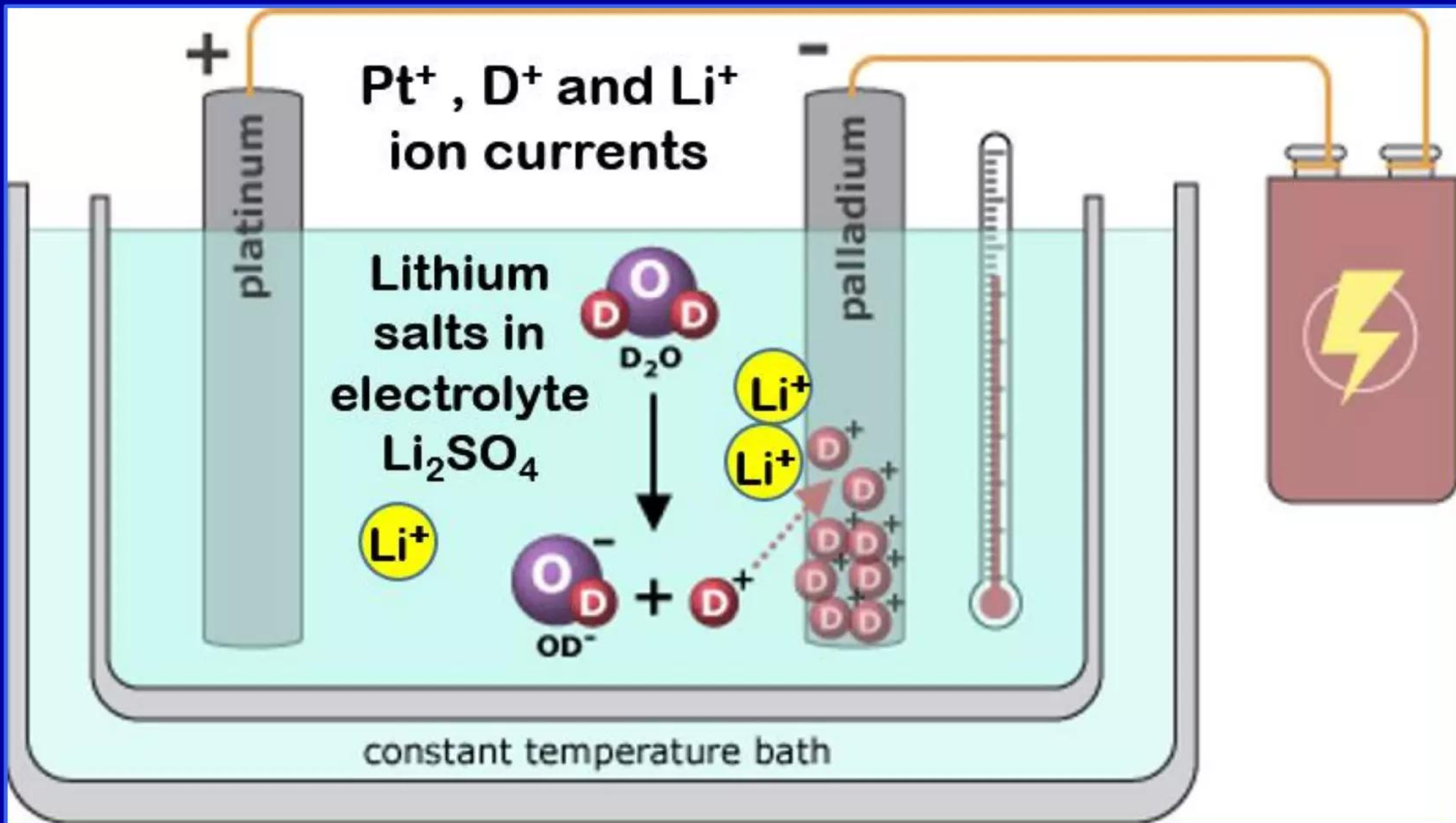
Overview of Pons-Fleischmann D_2O electrochemical cell

Platinum anode, Palladium cathode, Lithium salts, aqueous electrolyte

Pt anode

Pd cathode

DC electrical power source



Adapted from source: http://undsci.berkeley.edu/article/0_0_0/cold_fusion_03

Neutrons captured by Lithium (Li) in electrochemical cells

Short series of nuclear reactions releases more energy than D+T fusion

No dangerous radiation emitted by process; already demonstrated in laboratory

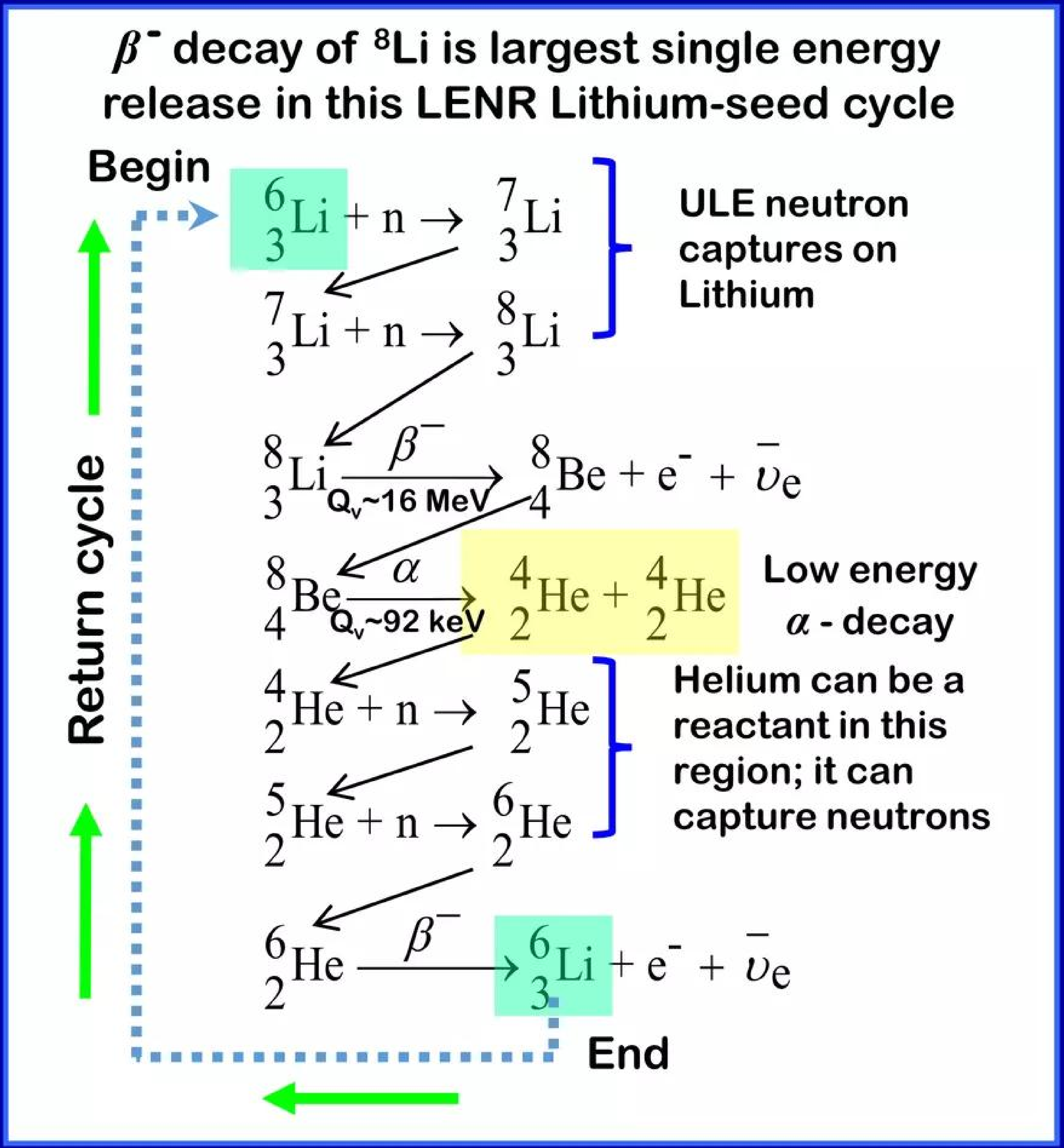
Li-seed LENR reaction cycle shown below produces detectible quantities of Helium-4 (^4He)

Lithium-6 + 2 ULE neutrons → 2 Helium-4 + beta particle + 2 neutrinos + Q-value of ~26.9 MeV

This particular cyclical LENR pathway can release about the same amount of energy as the D-T fusion reaction without creating any MeV-energy energetic neutrons, hard gamma radiation, or radioactive isotopes. Although portion of 26.9 MeV in excess nuclear binding energy released is lost ("haircut") with emitted neutrinos, much still remains in kinetic energy of two helium atoms (which are low-energy alpha particles), and very energetic beta particle

In this case, local matter heated-up by scattering of low-energy alpha and much-higher-energy beta particles; heavy-mass electrons present in LENR-active sites will convert any locally produced hard gammas or X-rays (coming from whatever process) directly into infrared heat

Neutron-catalyzed Lithium LENR cycle



Widom-Larsen theory explains *e* + *p* in condensed matter

Combines many-body collective effects + Q-M entanglement of particles

No “new physics” in W-L: embodies novel extensions of well-established physics

- ✓ Since 1989, most previously proposed theories of LENRs presumed that Coulomb barrier-penetrating D-D fusion was taking place in LENRs. However, these earlier theories incorporated many *ad hoc* assumptions, invoked questionable “new physics,” and were readily dismissed for good reasons by mainstream physicists and chemists
- ✓ Prior Widom-Larsen, no comprehensive theory of LENRs existed that was consistent with known physics and could explain results of ordinary hydrogen as well as deuterium experiments, correctly identify the cause of complex transmutation products, and be able to calculate observed reaction rates from first principles; only theory able to explain Prof. John Huizenga’s “three miracles” discussed in his highly critical 1993 about “cold fusion”
- ✓ W-L theoretical work involves Standard Model interactions and many-body collective quantum mechanical effects: explains all good experimental data on LENRs dating back to early 1900s, especially absence of dangerous MeV-energy neutron or gamma radiation and negligible production of long-lived radioactive wastes; predicts a variety of new types of experimentally verifiable phenomena in condensed matter systems and magnetic flux tubes

Widom-Larsen theory shows how to increase reaction rates

Maximize density of $e^{-}*p^{+}$ or $e^{-}*d^{+}$ reactants and amounts of input energy

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

- ✓ Term $(\beta - \beta_0)^2$ in our published rate equation reflects the degree to which heavy-mass (renormalized) $e^{-}*$ electrons in LENR-active surface sites exceed minimum W-L threshold ratio for electroweak neutron production, β_0
- ✓ We predict that, all other things being equal, the higher the surface area-density of $e^{-}*p^{+}$ or $e^{-}*d^{+}$ reactants and greater the rate and quantity of appropriate forms of nonequilibrium energy inputs, the higher the rate of ULE neutron production in nm- to μm-scale LENR-active sites in properly engineered, nanotech-based, LENR thermal power generation devices
- ✓ LENR transmutation network pathways comprising series of picosecond-duration neutron captures interspersed with serial beta-decay cascades can release substantial amounts of nuclear binding energy, much of it in form of usable process heat, over periods ranging from hours to weeks --- depends on target fuels, pathways used, and availability of input energy

Publications about the Widom-Larsen theory of LENRs

Index provides comprehensive guide to available online information

"Ultra low momentum neutron catalyzed nuclear reactions on metallic hydride surfaces"
A. Widom and L. Larsen (author's copy)
European Physical Journal C - Particles and Fields 46 pp. 107 - 112 (2006)
http://www.slideshare.net/lewisglarsen/widom-and-larsen-ulm-neutron-catalyzed-lenrs-on-metallic-hydride-surfacesepjc-march-2006

"A primer for electro-weak induced low energy nuclear reactions"
Y. Srivastava, A. Widom, and L. Larsen (author's copy)
Pramana - Journal of Physics 75 pp. 617 - 637 (2010)
http://www.slideshare.net/lewisglarsen/srivastava-widom-and-larsenprimer-for-electroweak-induced-low-energy-nuclear-reactionspramana-oct-2010

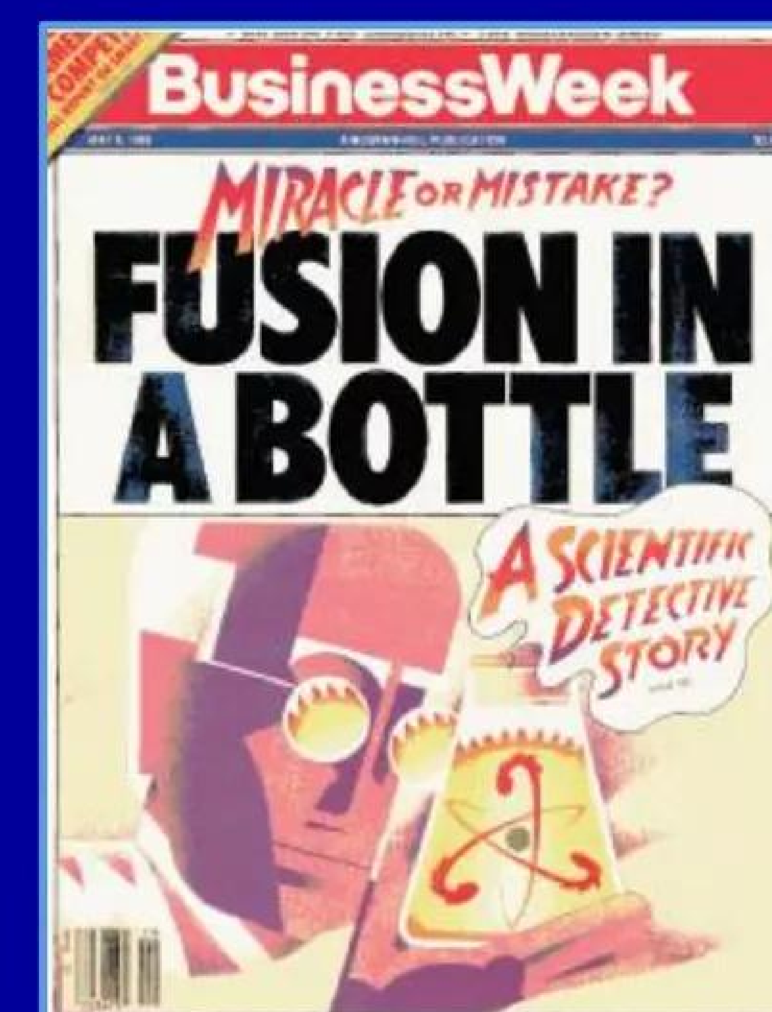
"Theoretical Standard Model rates of proton to neutron conversions near metallic hydride surfaces"
A. Widom and L. Larsen
Cornell physics preprint arXiv:nucl-th/0608059v2 12 pages (2007)
http://arxiv.org/pdf/nucl-th/0608059v2.pdf

"Index to key concepts and documents" all hyperlinks in document are live
v. #21 updated and revised through Sept. 7, 2015
L. Larsen, Lattice Energy LLC, May 28, 2013 [133 slides] download is enabled
http://www.slideshare.net/lewisglarsen/lattice-energy-llc-hyperlinked-index-to-documents-re-widomlarsen-theory-and-lenrs-september-7-2015

Synopsis of “Fusion Fiasco”

Recent history of LENRs begins with “cold fusion” debacle in 1989

Hundreds of news stories and more than two dozen books have been written about the Deuterium “cold fusion” debacle involving two University of Utah electrochemists, Profs. Stanley Pons and Martin Fleischmann, that occurred from March 1989 to March 1990, when “cold fusion” was declared dead by David Lindley, an Editor at *Nature*. Why would anyone ever want to read yet another popular science account of an extensively reported episode concerning what is near-universally regarded as bad science, as suggested by the title of Prof. John Huizenga’s highly critical 1993 book, “Cold Fusion: The Scientific Fiasco of the Century”?



Synopsis of "Fusion Fiasco"

Krivit paints vastly more accurate picture of what happened back in 1989

Those interested in learning what really happened during this short period of ferocious scientific controversy that marks the beginning of a new conceptual paradigm shift in nuclear science should read the fact-filled 531 page book, "Fusion Fiasco."

Thanks to having unprecedented access to never-before-publicly-revealed U.S. government documents as well as crucial technical insights provided by a new explanatory theory (Widom & Larsen, 2005 --- covered in Krivit's first book in a three volume series, "Hacking the Atom"), investigative science journalist Steven Krivit paints a radically different picture of what actually transpired behind-the-scenes and what senior Dept. of Energy decision makers truly knew about excellent data produced in experiments quietly conducted by U.S. government scientists in 1989-90 in an effort to technically evaluate and confirm or reject Pons & Fleischmann's results.

Synopsis of "Fusion Fiasco"

Refutes widely held belief that Pons & Fleischmann were incompetent

"End of Cold Fusion in Sight"

"Although the evidence now accumulating does not prove that the original observations of cold fusion were mistaken, there seems no doubt that cold fusion will never be a commercial source of energy."

Op-ed piece by John Maddox, Editor of *Nature* 340 (July 6, 1989)

"Fusion fiasco" refutes widely held presumptions that Pons & Fleischmann were technically incompetent and guilty of wishful delusion about their reported experimental data. Instead, Krivit convincingly shows why the embattled duo's controversial excess heat measurements were probably correct, although (for reasons now understood in 2016) reproducibility of Pons & Fleischmann's' calorimetrically measured excess heat results were fiendishly difficult to achieve with technical knowledge available in 1989.

Synopsis of "Fusion Fiasco"

ERAB experimental data clearly showed effects of nuclear processes

The book reports on previously unpublished, 'buried' experimental data produced and reviewed by U.S. government scientists during 1989. In April 1989, under the auspices of the U.S. Dept. of Energy the government established and organized a so-called ERAB board to evaluate Pons & Fleischmann's experimental discovery to determine whether the observed results were real physical effects, not artifacts or blundering experimental errors. Accordingly, many scientists worked feverishly at different national nuclear and military laboratories to rapidly collect crucial experimental observations with P&F-type D_2O electrochemical cells; review meetings also occurred

Thanks to "Fusion Fiasco," we now know this new experimental data revealed that there was unequivocal evidence for occasional inexplicable excess heat production, obvious nuclear transmutations (including large isotopic shifts), occasional production of very small amounts of Tritium, and small random bursts of low energy neutrons. Absence of large emissions of deadly energetic neutron and gamma radiation during experiments suggested that the hard-to-reproduce process was indeed nuclear, but it was most likely not D-D fusion.

Synopsis of "Fusion Fiasco"

Pons & Fleischmann claim excess heat beyond chemical process

Based on their experimental data they speculated D+D fusion caused results

There were very serious paradigmatic problems with their Deuterium fusion hypothesis

- ✓ No energetic neutrons were being detected by anyone that were commensurate with calorimetrically observed amounts of excess heat; this was in conflict with well-established experimental knowledge about the D+D fusion reaction: expected MeV neutron fluxes should have killed all the experimenters in lab with deadly radiation
- ✓ No energetic gammas were being detected by anyone that were commensurate with measured amounts of excess heat; this was also in direct conflict with well-established knowledge about D+D fusion reaction: theoretically, expected MeV gamma fluxes should have killed experimenters with bio-deadly ionizing radiation
- ✓ Excess heat results *very* difficult to reproduce; based on sketchy information about experimental design initially provided by P&F, no one was able to reliably produce substantial amounts of excess heat and/or He-4: P&F's claims were hotly disputed
- ✓ Established theory about 2-body charged particle fusion reactions posited that star-like temperatures and pressures were absolutely required to trigger D+D nuclear fusion; electrolytic cells violated this key paradigm; ergo "cold fusion" was impossible
- ✓ Pons & Fleischmann's initial report and March 23 Univ. of Utah news conference was followed by one-day multinational workshop of 25 hand-picked scientists, including Dr. Richard Garwin, convened to discuss P&F's results in Erice, Italy on April 12, 1989

Synopsis of "Fusion Fiasco"

April 12, 1989: scientific debate at Erice meeting fixated on D+D fusion

Theoreticians tried increasing electrons' mass to increase fusion cross-sections

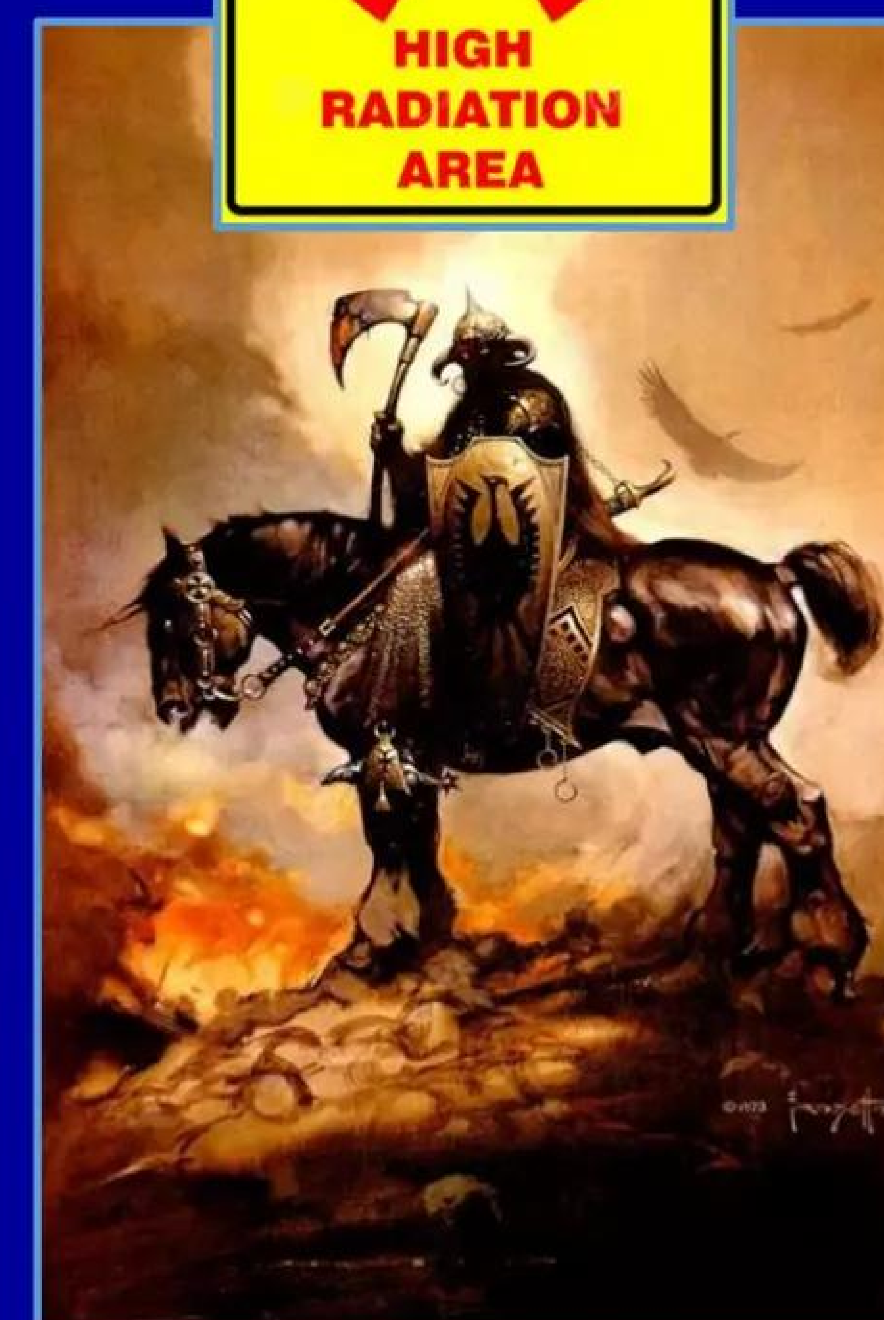
- ✓ General agreement that cross-section for spontaneous $d^+ + d^+$ (D+D) nuclear fusion reactions inside a Palladium hydride lattice was roughly on the order of $3 \times 10^{-64} s^{-1}$
- ✓ Assuming that calorimetrically observed fluxes of excess heat produced from electrochemical cells were measured accurately, theoretical problem was to find a plausible physical mechanism that could sufficiently increase D+D fusion cross-section so reaction rates were commensurate with excess heat measured in cells
- ✓ Generally believed that increased charge screening by electrons present in bulk Palladium lattice could sufficiently increase D+D reaction rates; however, in order to get this scheme to work they were forced to make *ad hoc* what if assumption that effective electron masses were somehow increased inside Palladium hydride lattice
- ✓ Koonin & Nauenberg (Univ. California) circulated preprint discussed at Erice which concluded that increasing electron masses by factors of 5 - 10 could increase D+D fusion rates high enough to explain observed heat production; however, they added a *caveat*, "we know of no plausible mechanism for achieving such enhancements." Walling & Simons (Univ. Utah) soon published another paper with same conclusions
- ✓ Widom & Larsen (2005) published mechanism that can increase electron masses by multiples sufficient to enable direct reactions of electrons with protons/deuterons

Synopsis of “Fusion Fiasco”

Erice preprint increased masses of electrons to explain fusion rates

Absence of energetic gamma and neutron radiation emission was inexplicable

- ✓ While increased electron masses might well explain the apparent high rates of D+D fusion, no existing theory had plausible mechanism for creating such mass increases
- ✓ For the most part, scientists were focused on trying to understand how D+D fusion reactions could work in Pd cathodes; most believed neutrons were not likely to be causative agents because: (a) only small, erratic bursts were occasionally detected; and (b) no one seriously considered the possibility of neutrons perhaps being created *in situ* ; they simply assumed that any neutrons observed from Pt/Pd cells *had* to come from D+D fusion
- ✓ Absence of large, easily detected fluxes of energetic gamma radiation in conjunction with production of excess heat was a mystery because all known fusion reactions will emit multi-MeV gammas; this also seemed to rule-out any involvement of neutrons in making heat because it was well-known that capture of neutrons on Pd almost invariably emits prompt and delayed energetic gammas



Frank Frazetta
“The Death Dealer”
(1973)

Synopsis of “Fusion Fiasco”

W-L answer key issue posed by Koonin & Nauenberg in Erice preprint

Abstract below is from Widom & Larsen’s *EPJC* paper published in March 2006

The sources of the electron mass renormalization via electromagnetic field fluctuations on metallic hydride surfaces and the resulting neutron production are the main subject matters of this work. The surface states of metallic hydrides are of central importance: (i) Collective surface plasma [11] modes are involved in the condensed matter weak interaction density of final states. The radiation frequencies of such modes range from the infrared to the soft X-ray spectra. (ii) The breakdown [12] of the conventional Born–Oppenheimer approximation for the surface hydrogen atoms contributes to the large magnitude of electromagnetic fluctuations. (iii) The neutrons are born with an ultra low momentum due to the size of the coherence domain of the oscillating protons. The coherence domains may be estimated to vary from about one to ten microns in length. The domains form a comfortable *cavity* in which to fit the neutron wavelength. The long final state neutron wave length allows for a *large* neutron wave function overlap with *many* protons, which increases the coherent neutron rate. Some comments regarding nuclear transmutation reactions that result from ultra low momentum neutron production will conclude our discussion of neutron catalyzed reactions.

http://www.slideshare.net/lewisglarsen/widom-and-larsen-ulm-neutron-catalyzed-lenrs-on-metallic-hydride-surfacesepjc-march-2006

Synopsis of "Fusion Fiasco"

Occurrence of neutron production in P&F cells deemed unlikely in 1989

Widom & Larsen provided physics by invoking many-body collective Q-M effects

- ✓ If neutrons were behind LENRs, is there a nuclear process that can create them *in situ* in electrochemical cells? Yes, an electroweak reaction between an electron and a proton ($e^- + p^+$) or an electron and a deuteron ($e^- + d^+$) will produce one or two neutrons respectively plus a neutrino photon; back in 1989, physicists believed that such reactions could only occur in stellar supernovas and particle accelerators
- ✓ Possibility of $e + p$ was not seriously considered in 1989 because it seemed *a priori* impossible to trigger electroweak reactions in P&F cells & observed neutron fluxes were at best sporadic and seemingly minuscule; zero evidence for capture gammas
- ✓ However, in 1989 it was well-known amongst some nuclear and astrophysicists that the cross-section for a spontaneous electroweak reaction between free electron and free proton while at rest had low value of ~ $1.18 \times 10^{-44}/cm^2$ [source: H. Bethe]
- ✓ Unfortunately, ~1.3 MeV energetic barrier for electroweak reactions between $e^- + p^+$ or $e^- + d^+$ is much higher value than what is needed to trigger D+D fusion reactions; that would have ruled-out the electroweak possibility in minds of most physicists
- ✓ Answer to this conundrum finally provided by Widom & Larsen 16 years later in 2005 by invoking many-body collective effects along with quantum entanglement of charged particles (SP electrons and protons or deuterons) in condensed matter

Synopsis of “Fusion Fiasco”

Experimental data from Oct. 1989 meeting included in ERAB evaluation

Naval Research Laboratory and Lawrence Livermore National Laboratory had data

NRL and LLNL reported experimental data with P&F-type electrochemical cells at meeting

Proceedings: EPRI-NSF Workshop on Anomalous Effects in Deuterided Metals

October 16-18, 1989
Washington, D.C.

August 1993

Screen capture image of October 1989 EPRI-NSF workshop *Proceedings* cover page

Proceedings of invitation-only workshop was not published until August of 1993. Released with no fanfare and limited distribution of 100 hardcopies; still unavailable on the Internet. By time of its release, P&F had already fled to France and subject was globally proclaimed dead and buried

Synopsis of "Fusion Fiasco"

Rolison & O'Grady's experiments used P&F-type electrochemical cells

Mass spectroscopy used to measure Pd isotopes on surfaces of Pd cell cathodes

Data was reported at Washington, D.C. EPRI-NSF workshop in mid-October 1989

Section 10

MASS/CHARGE ANOMALIES IN Pd AFTER
ELECTROCHEMICAL LOADING WITH DEUTERIUM

Debra R. Rolison and William E. O'Grady

Naval Research Laboratory

Screen capture image of cover page for Section #10 in EPRI-NSF workshop *Proceedings* document

Synopsis of “Fusion Fiasco”

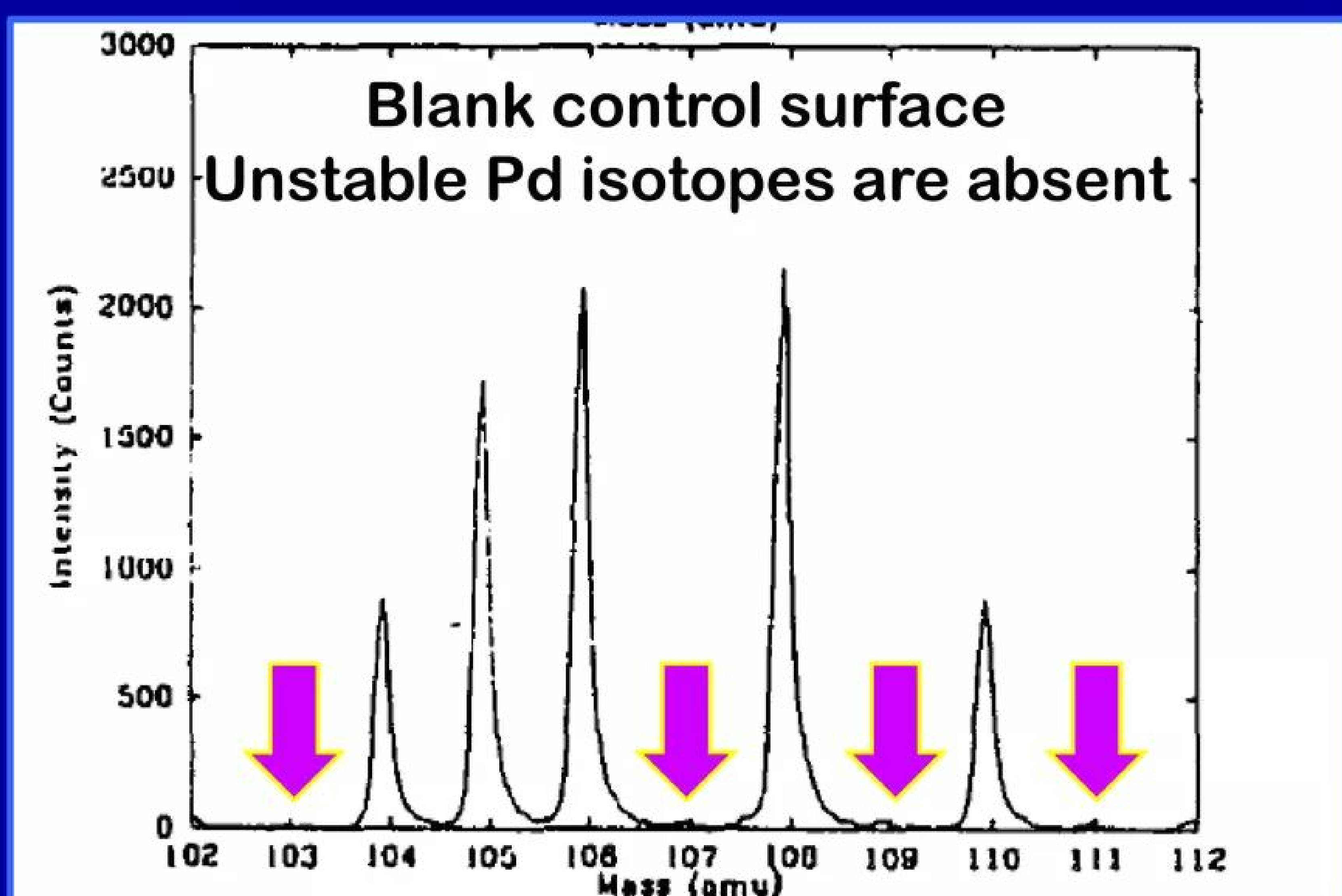
Analyses of Rolison & O’Grady’s Pd cathodes showed isotopic shifts

Palladium isotopic ratios were substantially shifted at conclusion of experiments

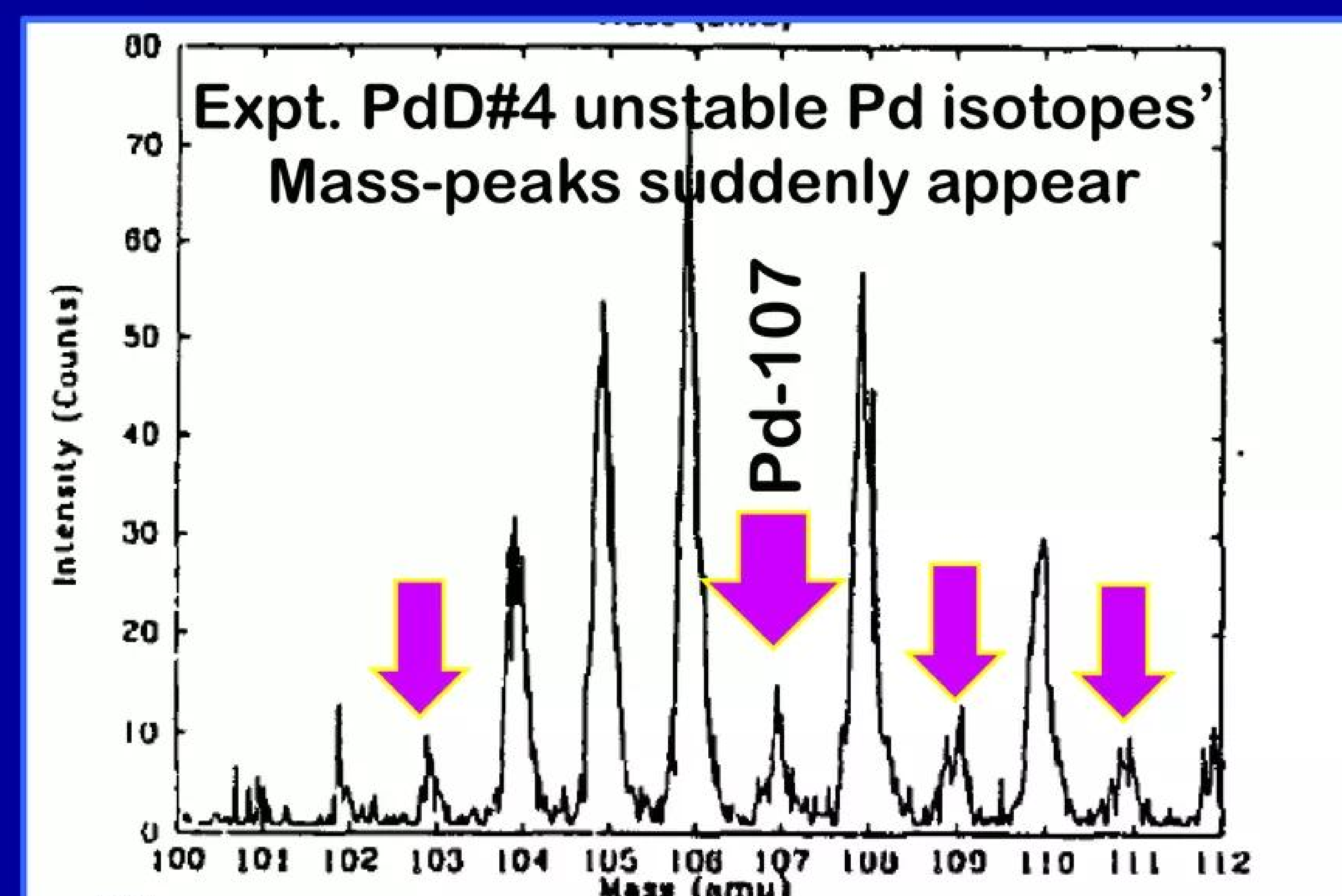
Mass peaks (amu) correspond to intensities (~amounts) of Palladium isotopes

> Our experiments with the electrolysis of Pd foil in D_2O did not produce large neutron fluxes, and due to the small volume of the foil, calorimetric measurements were precluded. However, surface analyses by time-of-flight secondary mass spectrometry (TOF-SIMS) of the electrolyzed Pd revealed anomalies with electrolysis. TOF-SIMS was used to survey the effect on the Pd isotopic distribution with electrolysis in D_2O and H_2O. We report here an enrichment of m/z 106 and a diminution of m/z 105 in the surface/near-surface layers of Pd electrolyzed in D_2O. No enrichment of m/z 106 was observed for the starting Pd material or for Pd electrolyzed in H_2O.

Before: pristine surface of Palladium cathode



After: relative amounts change; new peaks appear



Screen capture image of Fig. 1 on page #10-3 in EPRI-NSF workshop *Proceedings* document

Synopsis of "Fusion Fiasco"

Analyses of Rolison & O'Grady's Pd cathodes showed isotopic shifts

Experiment PdD#4 had a 50%enrichment in Pd-106; Pd-105 actually went *down*

Curious as to the depth of this m/z anomaly, we acid etched a piece from PdD#10 - the sample with the most pronounced enhancement at m/z 106 (and diminution of the remaining naturally occurring isotopes) - with 1:1 $HCl:HNO_3$. The etching removes on the order of micrometers of material from the surface. After the acid etch the foil was once again shiny and crystal facets were again visible, i.e., it looked just like acid-cleaned, non-electrolyzed Pd foil. The TOF-SIMS results (Table II and Figures 2 and 3) show that this treated sample (PdD#11) is indistinguishable from the Pd blank. While the depth of the acid etch is on the order of 10 μm, the mass/charge anomaly is clearly not a bulk phenomenon.

The fact that the interior of the Pd remains isotopically normal implies two things: (1) that any isotopic scrambling is near surface; and (2) that the enhancement of m/z 106 does not derive from a long range isotopic separation - an isotopic redistribution which leaves the middleweight isotope enriched relative to the light- and heavyweight isotopes is puzzling, especially when the separation factors (calculated as the square root of the ratio of the masses) differ only by parts-per-thousand.

PdD#4, the sample with a nearly 50% enrichment at m/z 106, shows no m/z intensities consistent with zirconium isotopes in its TOF-SIMS spectrum, so the enrichment observed for this sample is not due to this happenstance interference. This sample was dissolved shortly after termination of charging for bulk analysis, so, unfortunately, it does not exist in a form permitting high-resolution, surface-sensitive mass spectrometric analysis. The origin of the m/z 106 enrichment and m/z 105 diminution for PdD#4 is still unknown, but it is not due to either plasma contamination from the conditions of the TOF-SIMS experiment or the zirconium contamination seen for PdD#10.

Screen capture snippets of text from page #10-7 in EPRI-NSF workshop *Proceedings* document

Synopsis of "Fusion Fiasco"

Analyses of Rolison & O'Grady's Pd cathodes showed isotopic shifts

Results explained by neutron captures on Pd but they were unwilling to claim it

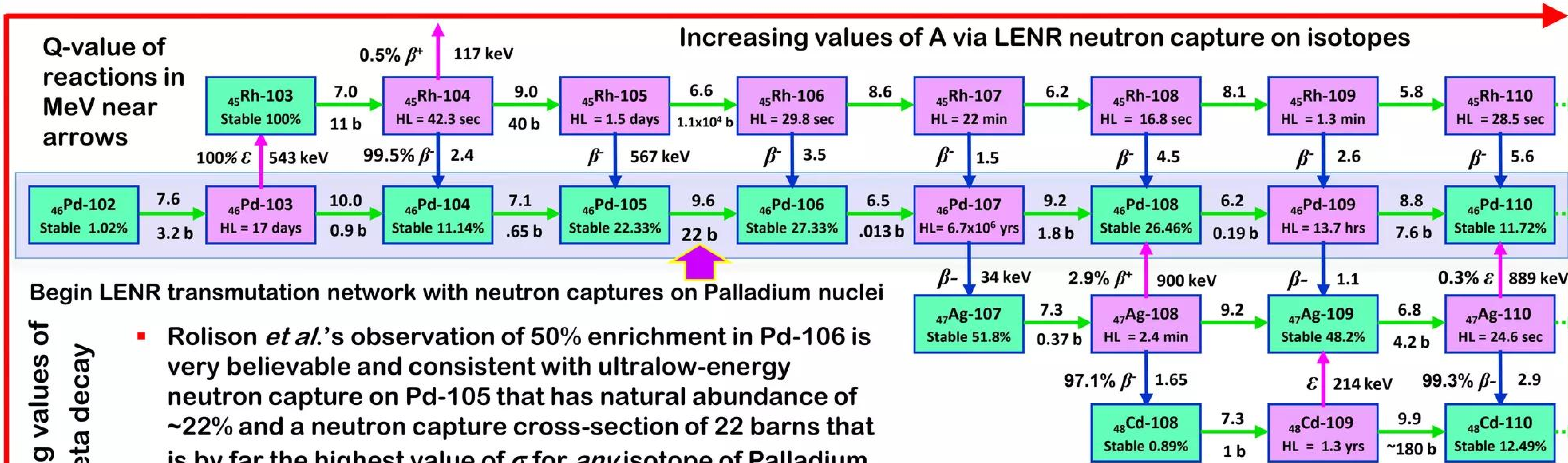
- ✓ Made strenuous efforts to conduct good experiments with accurate isotopic measurements; they were especially careful to exclude the possibility of external contamination as a source of the anomalies
- ✓ Looked for presence of energetic neutrons during experiments but did not observe any; did not attempt to measure excess heat calorimetrically
- ✓ Reported dramatic relative enrichment of Pd-106 and substantial parallel depletion of lighter Pd-105 isotope in very same electrochemical experiment
- ✓ Clearly observed the production of normally absent, unstable isotopes of Palladium (e.g., Pd-103, Pd-107, Pd-109, and Pd-111) during experiment PdD#4 (note post-experiment appearance of these additional Pd mass-peaks back in Fig. 1 shown earlier) but made no special note of it
- ✓ All this data is obviously well-explained by neutron captures on Palladium isotopes but Rolison *et al.* were reluctant to speculate because there was no clear evidence for large fluxes of energetic neutrons during the experiments
- ✓ Answers to this puzzling array of experimental data were finally provided by Widom & Larsen in arXiv preprint published in May 2005, 16 years later

Synopsis of “Fusion Fiasco”

Palladium isotopic data reported by Rolison *et al*. in 1989 are explained

Widom-Larsen neutron-catalyzed LENR transmutation network on Palladium (Pd)

In network diagram neutron captures go left-to-right and beta decays go downward



- Rolison *et al.*’s observation of 50% enrichment in Pd-106 is very believable and consistent with ultralow-energy neutron capture on Pd-105 that has natural abundance of ~22% and a neutron capture cross-section of 22 barns that is by far the highest value of σ for *any* isotope of Palladium
- Given that mass spec analysis was performed several months after electrolysis, it is not clear the all unstable Pd isotopes that might have been produced would still have signals above limit of detection. However, given the high enrichment of Pd-106, and given that Pd-107 has longish half-life of ~10^6 years, their Pd-107 peak is probably real

Depending on neutron fluxes and time, LENR transmutation network may continue further

When known, thermal neutron capture cross-section in barns (b) shown beneath green arrow

Note: large amounts of nuclear binding energy can be released via ULM neutron captures on Palladium isotopes per above network. Prompt gammas arising from neutron captures on isotopes are automatically converted directly into benign infrared (IR) photons by mass-enhanced electrons in active sites per the Widom-Larsen theory and as described in U.S. patent #7,893,414 B2

Synopsis of "Fusion Fiasco"

Edward Teller reported LLNL observed clear isotopic shifts in Lithium

Lithium-6 isotope had been significantly depleted on their Pd cathode surfaces

Result was unexpected and anomalous; it should only happen in stars or fission reactors

Lithium-6 depletion explained by low-energy neutron capture: $^{6}Li + n \rightarrow {}^{7}Li$

SUMMARY ITEMS

(1) Isotopic analysis of the electrode, especially of the surface (and of the electrolyte) should be considered at least as high of a priority as n, T, He-3 and He-4 (Isotopic analysis is reportedly about 10^8 less sensitive than He). Geophysics (and astrophysics) data are of similar priority as p, x-rays, gammas and betas. Teller stated Livermore has measured Li-6 depletion in 1st micron of surface (measured to 3 microns).

Note: there are two stable Lithium isotopes in Nature: Li-6 (natural abundance = 7.5%; thermal neutron capture cross-section = 940 barns) and Li-7 (natural abundance = 92.5%; thermal neutron capture cross-section = 45 millibarns)

Especially note that the thermal neutron capture cross-section for Li-6 is vastly larger than that for Li-7; if neutron fluxes are present, Li-6 will then preferentially deplete vs. Li-7 (which will increase in abundance due to neutron capture on much less abundant Li-6

Synopsis of "Fusion Fiasco"

Teller believed that ERAB data indicated non-fusion nuclear process

After upbeat Erice meeting and multiple credible reports of small neutron bursts in electrochemical cells, Admiral James Watkins (then U.S. Secretary of Energy) was eager to push potentially revolutionary work forward. April 18, he called emergency meeting to accelerate experimental work at national labs.

By late October 1989, a number of people in U.S. government nuclear science community clearly knew that there was a strong collection --- albeit not then publicly visible --- of experimental data indicating that Pons & Fleischmann had in fact discovered some type of hard-radiation-free nuclear process capable of operating in electrochemical cells. If true, such a development could have enormous implications for energy production if it could be commercialized.

This data was apparently convincing to Dr. Edward Teller, an early member of the WWII Manhattan Project to build the first atomic bomb and widely regarded as the 'father' of the first U.S. Hydrogen fusion bomb. In October 1989, after reviewing all the experimental data, Teller wrote a historically important letter (reproduced in Krivit's book) to participants at a non-public ERAB-related NSF-EPRI technical meeting in which he enthusiastically opined that a nuclear process seemed to be occurring in electrochemical cells, but it was unlikely to be fusion. He even speculated that, "Perhaps a neutral particle of small mass and marginal stability is catalyzing the reaction" i.e., something like a neutron.

Synopsis of "Fusion Fiasco"

Garwin and Huizenga used disinformation to discredit experimental data

Two well-respected scientists were situated at the central focal point of the ERAB's technical assessment process, Prof. John Huizenga (chemist and physicist who had worked on the Manhattan Project) and Dr. Richard Garwin (IBM Vice-President and physicist who had worked with Teller and Ulam on engineering the first Hydrogen bomb).

Unbeknownst to high-level technical decision makers such as Teller and Watkins, and for reasons that today seem inexplicable other than as a virulent intellectual reaction to a looming possibility that a major conceptual paradigm shift in nuclear theory might be necessary to understand whatever obscure nuclear processes had created ERAB's baffling collection of new experimental data, Garwin and Huizenga took it upon themselves to marginalize and even discredit data which indicated that nuclear processes were occurring in Pons & Fleischmann electrochemical cells.

Synopsis of "Fusion Fiasco"

Garwin inexplicably provided key non-public ERAB documents to Krivit

In the book, Krivit exposes details of Garwin and Huizenga's behind-the-scenes indirect manipulation of the attitudes of key decision makers, including creating very artful *ad hoc* rationales and disinformation crafted to convince other ERAB scientists to arbitrarily dismiss otherwise good experimental data.

Events show that they were willing to go to incredible lengths to achieve their objectives. In doing so, they didn't seem to be driven by noble scientific objectivity but by hidden agendas.

Paradoxically and inexplicably, the person who generously provided invaluable archival copies of many rare, non-public ERAB-related documents that enabled Krivit to piece all the long-buried pieces of the puzzle together was none other than Richard Garwin. Did he have late-career regrets about his earlier actions in 1989 and a change of heart? Who knows.

Synopsis of "Fusion Fiasco"

Thanks to Garwin and Huizenga ERAB concluded data was unconvincing

In 1989-90, Pons & Fleischmann were also besieged by legions of highly critical, deeply skeptical, and extremely vocal researchers in the mainstream scientific community outside of the U.S. government. Given the huge public outcry by doubters and in no small measure because of the internal machinations of Garwin and Huizenga inside ERAB's review process, in its final deliberations the ERAB scientific panel pointedly ignored other types of experimental data that were clearly consistent with operation of nuclear processes in electrochemical cells. Instead, ERAB based its conclusions exclusively on problematic, extremely difficult-to-repeat measurements of excess heat.

Unsurprisingly, the final ERAB report concluded that substantial government funding of programs to support any further R&D in the area should not be initiated and that "experimental results of excess heat from calorimetric cells reported to date do not present convincing evidence that useful sources of energy will result from the phenomena attributed to cold fusion."

Synopsis of "Fusion Fiasco"

Scientists' caustic reactions to heretical data indicate paradigm challenge

Perhaps without realizing it, the ERAB panel publicly conceded that a major conceptual paradigm shift *al la* Thomas Kuhn might be causing intense intellectual discomfort that was exhibited by many scientists as they reacted to the panel's impressive collection of valid but then-inexplicable experimental data. This new, heretical data seemed to indicate that there was triggering of poorly-understood nuclear reactions in aqueous electrochemical cells with only modest inputs of electrical energy at near-ambient temperatures and pressures.

In other words, exploding stars, fission reactors, and nuclear weapons were not necessarily required to induce nuclear reactions that can transmute elements.

Paradigm Shift

Thomas Kuhn wrote "The Structure of Scientific Revolution" (1962) in which he articulated and popularized the concept of a "paradigm shift." In this famous seminal book, Kuhn argued that truly important scientific progress is not gradual and evolutionary, but is better described as: "a series of peaceful interludes punctuated by intellectually violent revolutions" and in those dramatic upheavals "one conceptual world view is replaced by another."

Synopsis of “Fusion Fiasco”

ERAB report admits that paradigm shift may be needed if data is correct

Buried in the final ERAB report, the panel openly admitted that, “Nuclear fusion at room temperature, of the type discussed in this report, would be contrary to all understanding gained of nuclear reactions in the last half century; it would require the invention of an entirely new nuclear process.”

Ironically, Teller, ERAB panel members, and the many vocal critics were all correct in their opinions. We now know that paradigm-challenging nuclear reactions that occur in Pons & Fleischmann-type electrochemical cells are not fusion processes --- hot, cold, warm, or otherwise. However, just as Edward Teller had intuitively suspected, all the ERAB panel’s experimental data (that was not at all understood back in 1989-90) were in fact produced by non-fission, non-fusion nuclear processes catalyzed by neutrons.

The correctness of Teller’s prescient speculation about the mechanisms underlying this data was not understood until the first arXiv preprint of the Widom-Larsen theory of LENRs was published back in 2005, “Ultra low momentum neutron catalyzed nuclear reactions on metallic hydride surfaces,” A. Widom and L. Larsen arXiv.org > cond-mat > arXiv:cond-mat/0505026 https://arxiv.org/pdf/cond-mat/0505026v1.pdf A layman’s explanation of the Widom-Larsen theory is provided in Krivit’s first book in the series titled, “Hacking the Atom”

Synopsis of "Fusion Fiasco"

Few key players involved in events of the 1989-90 debacle are still alive

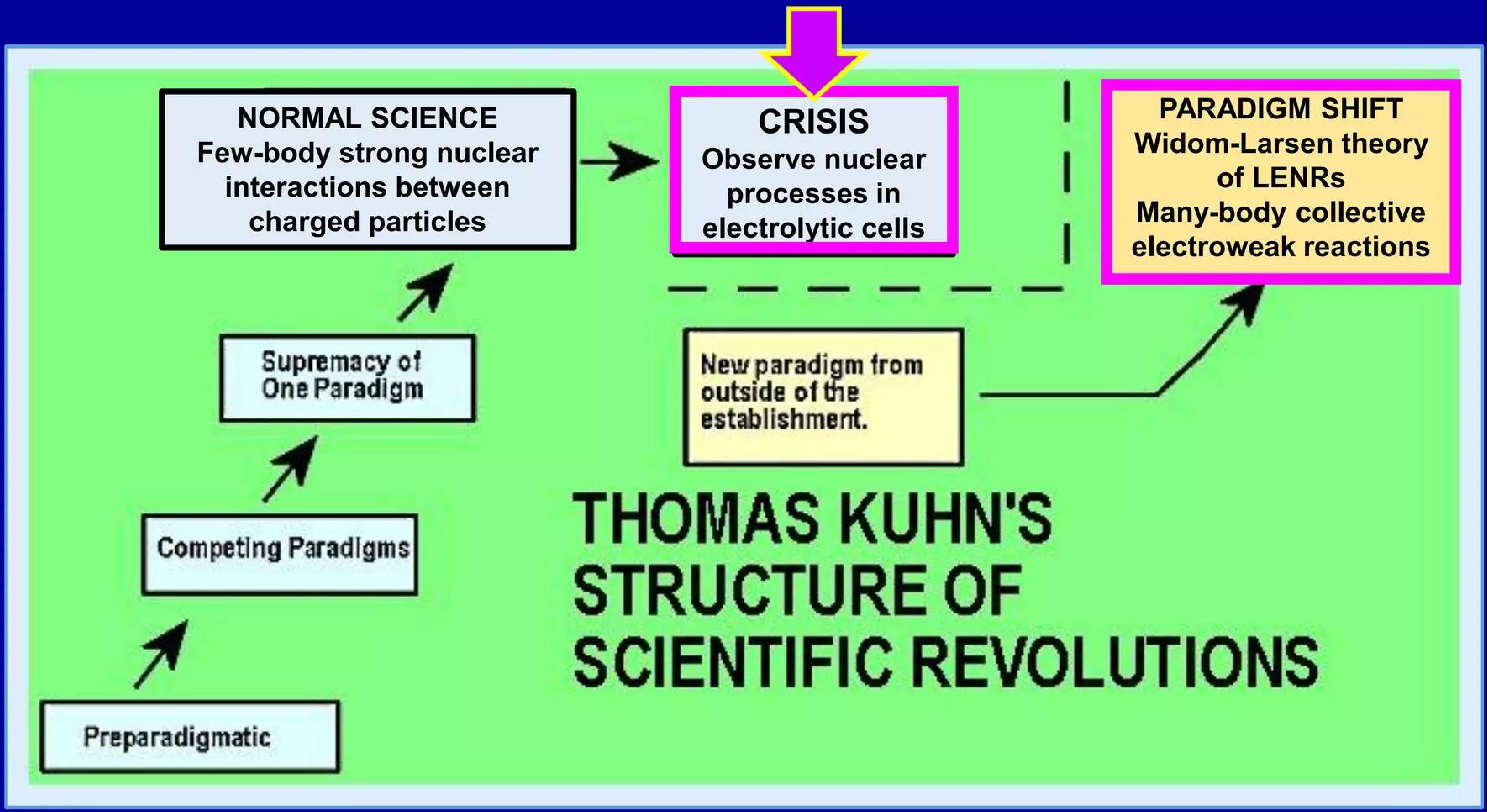
Epilogue:

Edward Teller died in 2003 and Admiral James Watkins in 2012. In an interview with Krivit in 2009, Martin Fleischmann admitted that he regretted calling their experimental discovery "cold fusion;" he died in 2012. John Huizenga died in 2014. Stanley Pons is still alive and living in hiding on a farm in the French countryside near Nice; he has not spoken with reporters for over two decades. Richard Garwin, who has been officially retired from IBM since 1993, at 88 remains an IBM Fellow Emeritus and continues to be active in U.S. national security work; he was awarded a Presidential Medal of Freedom by President Barack Obama in November 2016.

Widom-Larsen many-body collective theory of LENRs

Explains nuclear anomalies observed in electrolytic cell experiments

Posits collective neutron production via *e* + *p* and direct gamma conversion to IR



Adapted from source: https://www.facebook.com/pages/Thomas-S-Kuhn/14762913782

Paradigm shifts are " … a new way of seeing things"

"There is a … reason the old [dominant conceptual paradigm] … persists beyond its time, an economic one. Even if a novel principle *is* developed and does perform better than the old, adopting it may mean changing surrounding [economic, academic, and governmental] structures and organizations. This is expensive and for that reason may not happen … another reason is psychological. The old principle lives on because practitioners are not comfortable with the vision – and promise – of the new. Origination is not just a new way of doing things, but a new way of *seeing* things … And the new threatens … to make the old expertise obsolete. Often in fact, some version of the new principle [paradigm] has been already touted or already exists and has been dismissed by standard practitioners, not necessarily because of a lack of imagination. But because it creates a cognitive dissonance, an emotional mismatch, between the potential of the new and the security [and serenity] of the old."

W. Brian Arthur
"The Nature of Technology
What it is and how it evolves"
pp. 139 Free Press (2009)

SPASER (surface plasmon amplification by stimulated emission of radiation) device's local electric fields (2009)

http://opfocus.org/content/v7/s5/opfocus_v7_s5.pdf

Many-body collective effects span vast range of length-scales

Widom-Larsen theory and many-body collective effects extend from LENRs in condensed matter to environments found in high-current exploding wires, e.g., large wire inductors, up to large-length-scale, magnetically dominated regimes that occur in astrophysical systems

Length Scale	Type of System	Electromagnetic Regime	Many-body Collective Phenomena	Comment
Submicron	Certain earthly bacteria and some fungi	Very high, short-range electric fields	Transmutations, high level of gamma shielding	Obtain unavailable trace elements; survive deadly gamma or X-ray radiation
Microns	Hydrogen isotopes on metallic surfaces	Very high, short-range electric fields on solid substrates	Transmutations, high level of 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
Many meters to kilometers	Outer layers and atmospheres of stars (flux tubes)	Ideal and dusty plasmas: high mega-currents of electrons, protons, and ions inside large-scale, ordered magnetic structures with substantial internal electromagnetic fields	Energetic charged particles and neutrons (MeVs to EeVs), X-rays, gamma-ray bursts, and ultra-high-energy cosmic rays (TeVs to EeVs)	Provides explanation for heating of solar corona and radioactive isotopes in stellar atmospheres
Up to several AU (distance from earth to Sun)	Neutron stars and active galactic nuclei in vicinity of compact, massive objects (black holes)			Provides mechanism for creating extremely high energy particles in plasma-filled magnetic flux tubes with sufficient field strengths

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

W-L-S theory spans vast range of length-scales and energies

E-fields in condensed matter vs. B-field particle acceleration in plasmas

Short-range collective electric field effects dominate

Longer-range collective magnetic field effects begin to dominate

Long-range collective magnetic field effects dominate

local electric fields — **Low - medium electric and/or ion currents**

Regime: ultralow energy neutron reactions (LENRs) in condensed matter

$e^* + p^+ \rightarrow$ 1 neutron + neutrino or $e^* + d^+ \rightarrow$ 2 neutrons + neutrino

Neutron production, capture, release energy, and transmutation products

- Microorganisms – biological transmutations by certain types of earthly bacteria & fungi
- Pressure gradients across membranes – e.g., Iwamura, Li, & Arata-Zhang - 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, etc. - liquid or gas phase

Organized magnetic fields with plasmas — **High currents: electrons and/or ions**

- RF-triggered dusty plasmas - gas phase
- Current-driven dusty plasmas - gas phase
- Vacuum diodes – e.g. Proton-21, Kiev, Ukraine, Sandia NL (US) in 1970s - gas phase
- Exploding wires – e.g., Wendt & Irion, Chicago 1922; Z-pinch, Sandia NL - gas phase
- Piezoelectric and pyroelectric processes in solid-state materials – Carpinteri, Naranjo
- Magnetic flux compression generators, e.g. US (LANL), Russia
- Lightning (terrestrial, planetary, nebular), especially in dusty environments – e.g., Dwyer
- ULMN-catalyzed subcritical fission reactors (<<< nuclear waste) - reprocess old wastes

Higher fluxes of neutrons

Scales-up to very large length scales — Huge range of magnetic field strengths

Mega-scale currents

Mixed regime: high energy particle reactions and/or LENRs on dust

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 energy neutrons ……… MeV neutrons …GeV…TeVs …EeVs

Increasing neutron and charged particle energies

LENR transmutation effects were observed for >100 years

Not recognized as a result of nuclear process because no hard radiation

P&F (1989) but one of many instances where experimental results were dismissed

Timeline of selected discoveries and events; all data is explained by Widom-Larsen theory

Early 1900s: many famous scientists reported transmutation of elements during electric arc discharges

1922: Wendt & Irion report Helium produced in exploding wires; Rutherford dismissed results in *Nature*

1925: Nagaoka reported Gold produced during electric arc discharges on Tungsten; few believed him

1927: Millikan's PhD student reported heavy element transmutations in *Phys. Rev. Letters* ; not believed

Late 1930s to 1950: Dark Ages of LENR transmutation research; was not pursued by anyone anywhere

1951: Sternglass saw neutron production in discharges; consulted Bethe & Einstein but dropped work

1989: Pons & Fleischmann claimed D+D "cold fusion" observed in electrolytic cells; quickly discredited

1994: Texas A&M & BARC report transmutation of Carbon in arc discharges in ANS *Fusion S&T*; ignored

2002: Mitsubishi Heavy Industries reported transmutation of Cs → Pr in refereed *JJAP* ; widely doubted

2006: Widom & Larsen publish LENR theory's key parts in peer-reviewed *European Physical Journal C*

2012: Mitsubishi confirms Nagaoka's LENR transmutation path from Tungsten → Gold at ANS meeting

2013: Toyota confirms Mitsubishi's LENR transmutation of Cs → Pr in *Japanese Jour. of App. Physics*

2015: *New Energy Times* reveals a copy of the long-lost *Proceedings* of Oct. 1989 EPRI-NSF workshop

2016: Steven Krivit publishes "Lost history", third book in series "Explorations in Nuclear Research"

"Lost History"

Overview covers 100 years of previously inexplicable experimental data

https://www.amazon.com/dp/0996886419

Third book in the series "Explorations in Nuclear Research"

"Lost History"
"Explorations in nuclear research" (Volume 3)
Steven B. Krivit
Michael J. Ravnitzky, ed.
Cynthia Goldstein, ed.
Mat Nieuwenhoven, ed.
Pacific Oaks Press, San Rafael, CA
December 2, 2016 (380 pages)
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Applied nanotechnology required to commercialize LENRs

Large length scales

What was formerly thought impossible becomes possible by utilizing Widom-Larsen and applying nanotechnology

Nuclear-strength electric fields in μ-sized LENR-active sites enable $e + p$ reaction

Huge array of new technological possibilities and opportunities open-up at micron to nanometer length-scales

Widom-Larsen enables commercialization of LENRs

Applied nanotechnology and LENRs are mutually joined at the hip

Development risks can be reasonable thanks to Widom-Larsen and nanotech

Guided by physics of the Widom-Larsen theory, an opportunity to commercialize LENRs as truly green CO_2-free nuclear energy source has been enabled by a unique juxtaposition of very recent parallel advances in certain very vibrant areas of nanotechnology (esp. plasmonics), quantum entanglement, new innovations in nanoparticle fabrication techniques, as well as an array of new discoveries in advanced materials science.

Visualization of surface plasmon electric field strength (Volts/meter) - highest fields are dark red

Many LENR researchers have not been properly focused

Microscopic reproducibility of active sites is key to commercialization

- ✓ What some LENR researchers still don't realize is that many types of experimental systems that would not exhibit very much (i.e. little or none) excess heat when measured with very sensitive calorimetry, will in fact produce some microscopic, not-thermally-measurable amounts of LENR neutron-catalyzed transmutation products (that can be readily detected via mass spectroscopy with SIMS-EDX, TOF-SIMS, or even better, a Cameca nanoSIMS 50L) in nearly 100% of such experiments. In other words, many experiments might be effectively 100% reproducible when measured with mass spectroscopy on micron length-scales instead of gross macroscopic calorimetry. All this invaluable isotopic experimental data is simply lost and unavailable when scientists don't utilize correct analytical tools required to observe microscopic amounts of produced LENR transmutation products in device materials measured post-experiment
- ✓ Researchers who are lacking such powerful micro-analytical tools such as SIMS, TOF-SIMS, or nanoSIMS will be oblivious to what is really happening reaction-wise in their experimental systems. Unlike many of the American LENR researchers, large Japanese companies like Mitsubishi Heavy Industries and Toyota, for example, have consistently done a better job with microscopic measurements of materials at conclusion of experiments

Widom-Larsen theory enables commercialization of LENRs

Microscopic reproducibility of active sites is key to commercialization

- ✓ Where many experimentalists in LENRs have gone totally awry for 27 years is that they have been focusing primarily on trying to achieve macroscopic reproducibility of excess heat production, e.g. at level of a 1 cm^2 Pd cathode in a P&F-type electrochemical cell, without having a deep, requisite understanding of crucial microscopic physics details that govern the operation of tiny nm to micron-scale LENR active sites
- ✓ To commercialize LENRs, one must first achieve reliable microscopic reproducibility of active sites and then master high-volume fabrication of their nanoparticulate structural precursors. Possession of these two critical technical capabilities is mandatory for developing successful LENR device engineering programs that can lead to reliable production of commercially relevant, macroscopic amounts of excess heat for long time-periods in thermal power generation systems
- ✓ Nanostructures that are present around putative micron-scale, many-body LENR active sites must be correctly designed and purposely fabricated *in situ* to guarantee nuclear-strength local electric fields in those sites; then mandatory energy input is needed to create neutrons

Widom-Larsen theory enables commercialization of LENRs

Microscopic reproducibility of active sites is key to commercialization

- ✓ In successfully fabricated primitive laboratory devices typical of today, LENRs can presently reach temperatures of 4,000 - 6,000^{o} K in relatively small numbers of microscopic LENR-active sites located on device surfaces. Evidence for the existence of such extremely hot localized sites is provided in post-experiment SEM images of working surfaces wherein distinctive crater-like structures are visible; these features are produced by rapid heat releases in LENR-active sites that briefly create local high temperature flash-boiling of metals like Palladium
- ✓ At present stage of LENR technology (TRL-2), trying to fabricate cm-scale and larger devices that can reliably and controllably produce macroscopically large fluxes of excess heat - "boiling a cup of tea" - is putting the cart before the horse
- ✓ Unlike its competitors, Lattice plans to use its unique proprietary knowledge of LENR devices and key operating parameters (e.g., achieving and maintaining very high local surface electric fields) to first get key LENR effects --- such as excess heat, transmutations --- working well microscopically. That is, to be able to reproducibly create purpose-designed nanoparticulate structures with their dimensions ranging from nanometers to microns that are fabricated using certain existing, off-the-shelf nanotechnology techniques/methods and then emplaced, along with suitable target fuel nuclei (e.g., Lithium) in close proximity, at what will become LENR-active sites on the surfaces of appropriate substrates

Lattice's engineering plan has three key phases:

(1) Reproducible fabrication of well-performing LENR-active sites

(2) Scale-up heat output by increasing # of active sites per unit area/volume

(3) Select and integrate energy conversion subsystems suitable for specific applications

- ✓ Once microscopic reproducibility of active sites is achieved, output of LENR heat sources could be readily scaled-up, either by (1) fabricating larger area-densities of affixed nanostructures that facilitate formation of LENR-active hot spot sites on device surfaces, or by (2) injecting larger quantities of specially designed target fuel host nanoparticles into volumetrically larger reaction chambers containing turbulent dusty plasmas, with or without spatially organized magnetic fields present
- ✓ Variety of off-the-shelf energy conversion subsystems could potentially be integrated with commercial versions of LENR-based heat sources. These include: thermophotovoltaic; thermoelectric; steam engines; Rankine cycle steam turbines; Brayton cycle gas turbines, simple boilers, etc. Other more speculative possibilities involve new types of direct energy conversion technologies that are still in very early stages of development
- ✓ Lattice's nanocentric approach to R&D is unique by being interdisciplinary and directly guided by various proprietary insights enabled by Widom-Larsen theory of LENRs and related relevant knowledge borrowed from advanced materials science, plasmonics, nanotechnology, and chemistry

LENR active sites analogous to transistors in some ways

Key functional feature of transistors: ability to amplify Voltage: $V_{out} > V_{in}$

- ✓ Transistor is key active, fundamental component of modern electronics; replaced vacuum tube technology invented in 1904 that was physically larger, much more power hungry, and more expensive to manufacture
- ✓ First experimental Germanium semiconductor transistor was invented at Bell Labs in 1947; crude handmade device was approximately 0.5” in size and was capable of signal amplification, i.e. small changes in input voltage created large changes in output voltage ($V_{out} > V_{in}$). Ratio of V_{out} divided by V_{in} is called amplifying gain; other major use of semiconductor transistors is to function as electrically controlled switches
- ✓ Like transistors, LENR devices will function as a type of amplifier --- only instead of amplifying modest voltage of an electrical signal, LENRs amplify input energy. Electronic or chemical energy on scales of electron Volts (eVs) is directed and concentrated to create neutrons in a radiation-free electroweak $e + p$ or $e + d$ reaction. Those neutrons are captured by target fuel atoms in an LENR device which releases nuclear binding energy on a scale of Mega-electron Volts (MeVs - 10^6 eVs). With all LENRs, maximum theoretical device gain of $Energy_{output}$ / $Energy_{input}$ depends on target fuel that captures neutrons. Energetic gain with Deuterium and Lithium is 34x but Hydrogen with Nickel averages ~10x, depending upon Ni isotopic mix

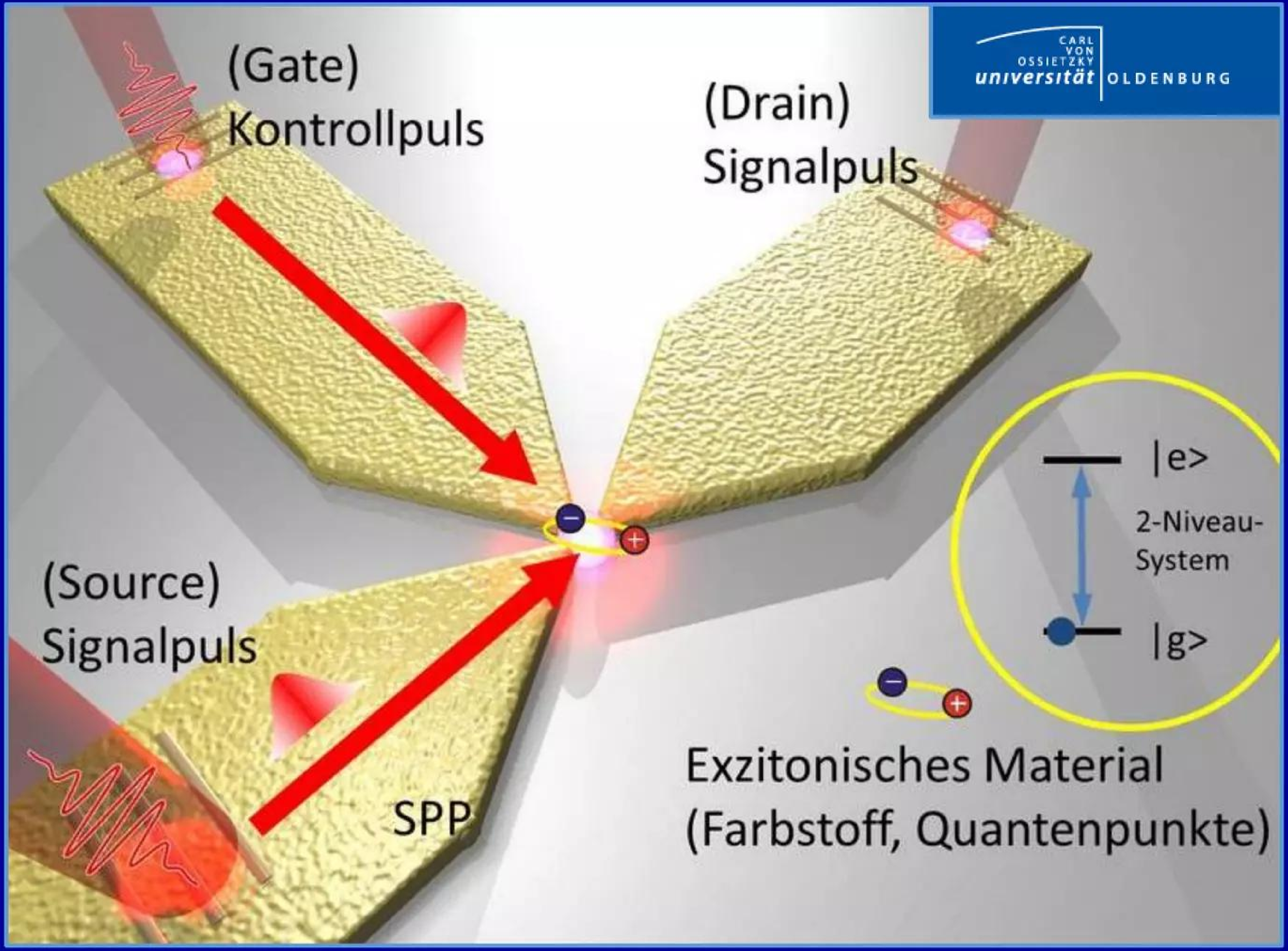
Comparison: attributes of LENR active sites vs. transistors

Attribute	LENR active sites	Transistors
Key functional use	Input energy amplification	Signal amplification and switching
Operant forces in applicable physics	Electromagnetic, electroweak, and strong nuclear force are all important	Strictly the electromagnetic force; solid-state condensed matter
Importance	Triggers release of 'green' nuclear energy under moderate conditions	Key active component in modern electronic devices like microchips
Proton sources	Hydrogen or Deuterium	Not applicable
Electrons	Surface plasmons (metallic surfaces) and at certain metal-oxide interfaces; ***π:*** aromatic rings, graphene, fullerene	Conduction electrons - new future types of transistors may use surface plasmons instead of bulk electrons
Target fuel elements	Lithium, Carbon, Nickel, etc. - almost any isotope that will capture neutrons	Not applicable
Operating voltages	Vast range of experimental values: 2 V up to many thousands of Volts	Generally under several Volts except for high-power switching devices
Size	Ranges from 2 nm up to perhaps ~100 microns at the most	Current commercially available CMOS devices are at roughly 65 nm
Reusability	Individual sites will only be used once	In theory: enormous number of cycles
Manufacturing technologies, cost, and older preceding technologies that are or were threatened	By borrowing from existing nanotech fabrication techniques, they should be manufacturable in very high volumes at low cost; could compete directly against chemical power technologies	Experience curve effect and high unit volumes have enabled enormous decreases in size and device cost since 1950s. Almost totally replaced preceding vacuum tube technology

LENR active site physics deeply connected to plasmonics

Surface plasmons on metal transport input energy to LENR active sites

Univ. of Oldenburg: ultrafast nano-optics group developing all-photonic transistor



https://www.uni-oldenburg.de/en/physics/research/pictures-and-videos/

Mimic semiconductor industry to dominate key markets

Maximize total unit volumes & ride cost curve to attack the competition

Some aspects of future transistor and LENR technology could converge & overlap

- ✓ LENR systems could exploit experience curve effect to reduce manufacturing costs; same as successful market penetration strategies used by electronics manufacturers; e.g., microprocessors, memory chips, PCs, and smartphones
- ✓ As product manufacturing experience accumulates and internal build costs are progressively reduced, leverage longer operating life and huge energy density advantages of LENRs (thousands of times larger than any chemical technology)
- ✓ Price LENR-based systems to drastically undercut price/performance features provided by competing electrochemical battery energy storage products and combustion-based power generation systems. Strategy can be used to attack portable, stationary, mobile, and central station power generation markets
- ✓ Small-scale LENR systems might seem to be light years away from being able to compete with huge 500 - 1,500 MW coal-fired and Uranium-fission power plant behemoths. However, please recall history of personal computers versus large mainframes. When PCs were first introduced 42 years ago, mainframe computer manufacturers regarded them as just toys, information processing jokes of no consequence. Less than 10 years later, mainframe companies weren't laughing any more. Today, except for just a handful of hardy survivors like IBM, mainframe and minicomputer dinosaurs have disappeared, replaced by microprocessor arrays

Truly green nuclear power generation possible in near-future

> **"I have learned to use the word 'impossible' with the greatest of caution."**
> **Werner von Braun**

Technology of ultralow energy neutron reactions (LENRs) could enable future development of revolutionary MeV radiation-free, 'green' nuclear power sources that would be suitable for aircraft and vehicular propulsion as well as for stationary and portable power generation applications.

Benign, low-cost nanoparticulate LENR fuels could be used in a huge array of different types of LENR-based power sources. These fuels would have effective energy densities 5,000x larger than gasoline; enough onboard fuel for a manned aircraft or car to make a round-the-world trip would probably fit into just one or two large FedEx boxes.

Working with Lattice

Partnering on commercialization and consulting on certain subjects

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L. Larsen c.v.: http://www.slideshare.net/lewisglarsen/lewis-g-larsen-cv-june-2013

- ✓ Lattice welcomes inquiries from large, established organizations that have an interest in discussing the possibility of becoming Lattice's strategic capital and/or technology development partner
- ✓ Lewis Larsen also independently engages in fee-based consulting. This separate work covers subjects such as: micron-scale, many-body collective quantum effects in condensed matter; Lithium-ion battery safety engineering issues including minimizing risks for occurrence of thermal runaways; and development of ultra-high-temperature superconductors. Additional areas of expertise include: long-term strategic implications of LENRs for high cap-ex long term investments in power generation technology; energy storage technologies; and LENR impact on vehicle exhaust emissions. Will consult on these subjects as long as it does not involve disclosing Lattice proprietary engineering details relating to developing LENR power generation systems

