Lattice Energy LLC

Commercializing a next-generation source of green nuclear energy

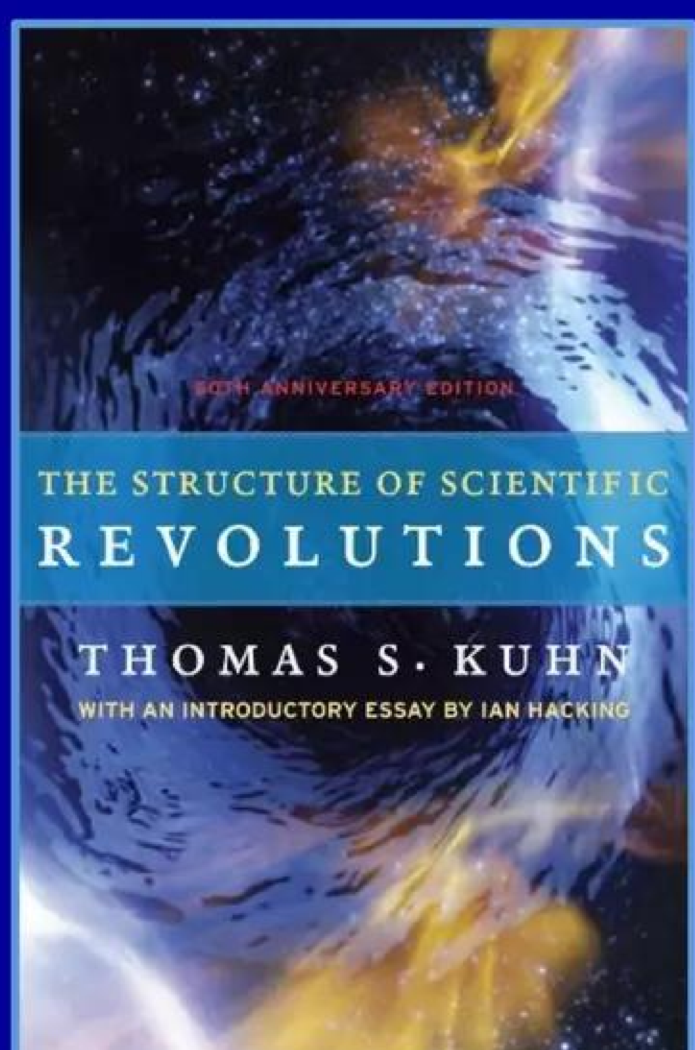
In 1989 some scientists knew neutrons were behind LENRs

Experimental data from national labs clearly showed neutron captures

Unequivocally good data was totally ignored by U.S. government and majority of scientists because it violated paradigms and existing theory couldn't explain it

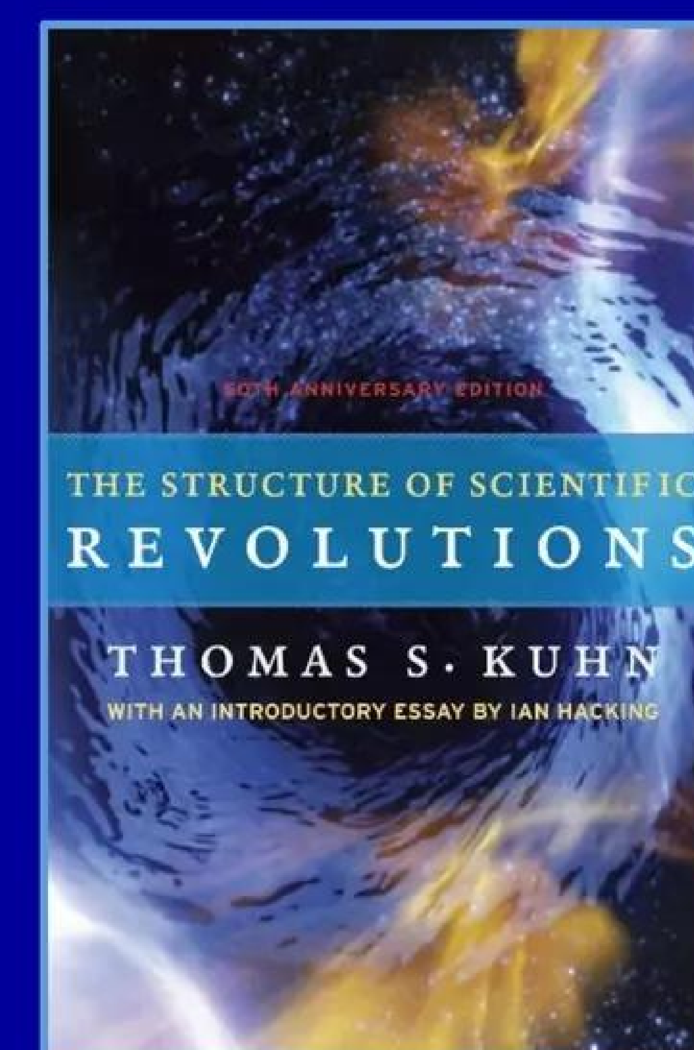
Lewis G. Larsen
President and CEO
Lattice Energy LLC

May 13, 2015



"Normal science does not aim at novelties of fact or theory and, when successful, finds none."

T. Kuhn "The Structure of Scientific Revolutions" (1962)



Contact us directly for further details: 1-312-861-0115
lewisglarsen@gmail.com

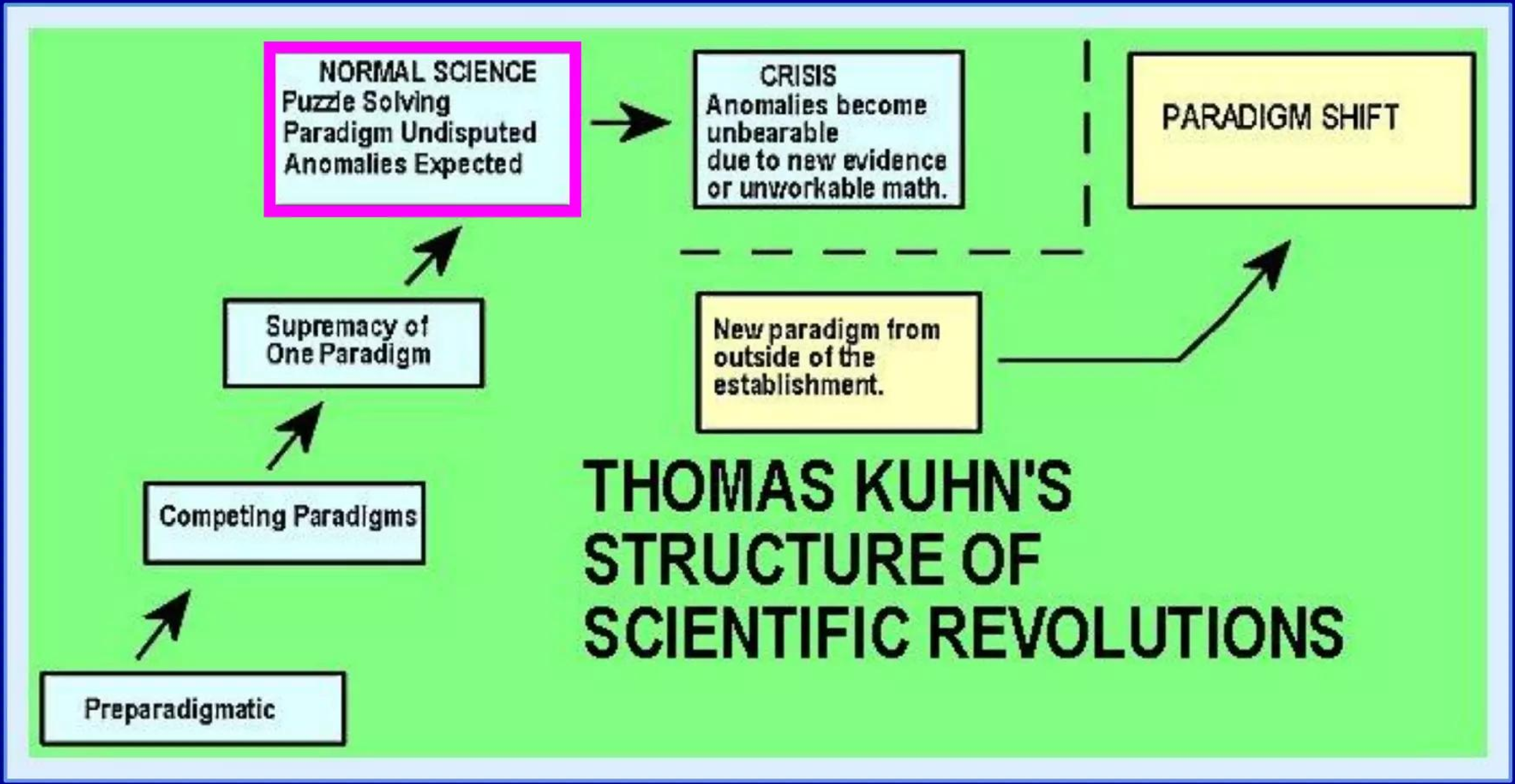
http://www.slideshare.net/lewisglarsen/presentations

May 31, 2015: added 23 slides to further explain history of nuclear paradigm shift and how W-L answers key questions

In 1989 scientists embraced "normal science" *a la* Kuhn

Confronted with nuclear anomalies in Pons & Fleischmann experiments

Data didn't fit established paradigm about D-D fusion or other nuclear processes



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

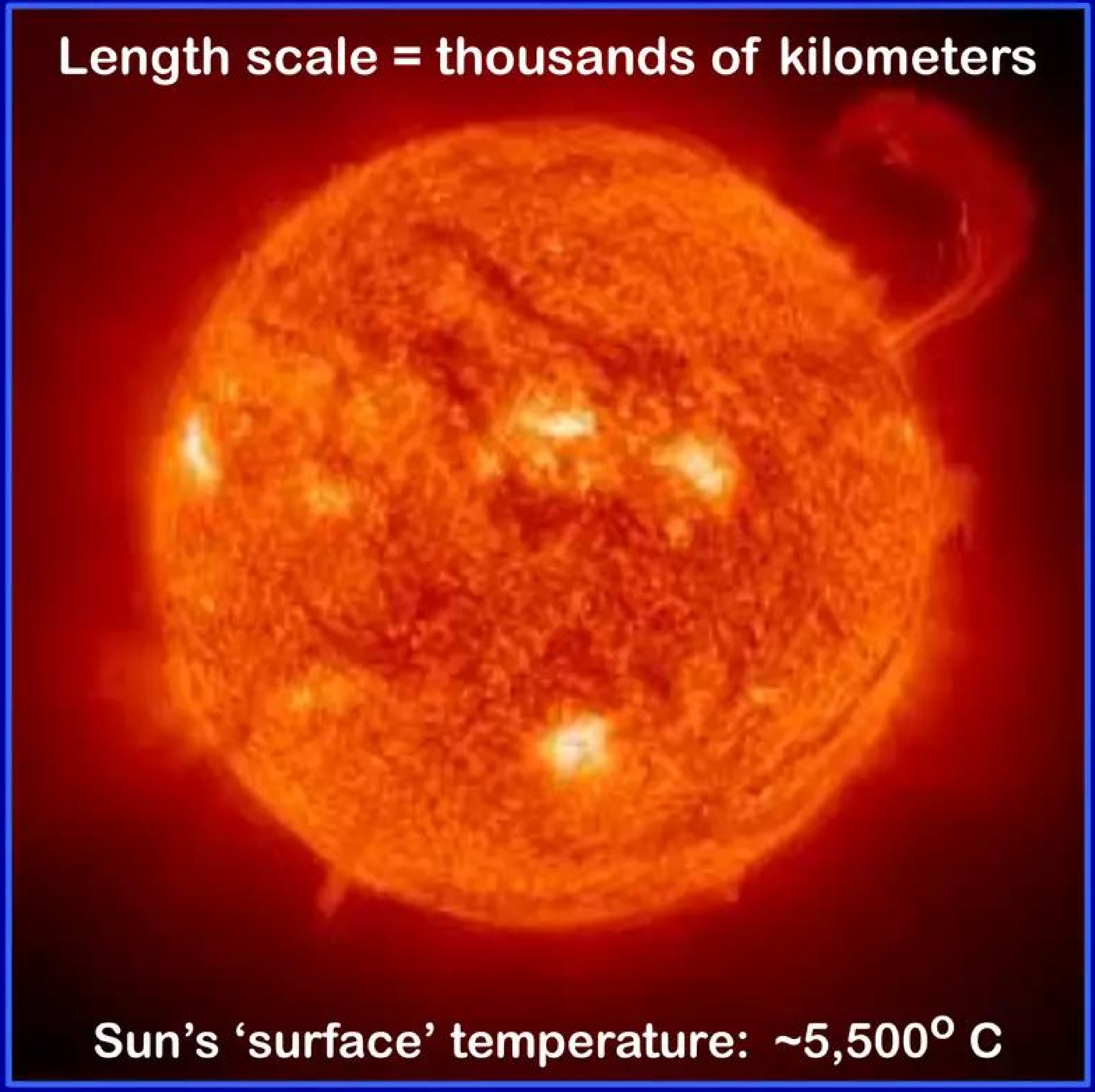
Paradigm: fusion reactions cannot occur in chemical cells

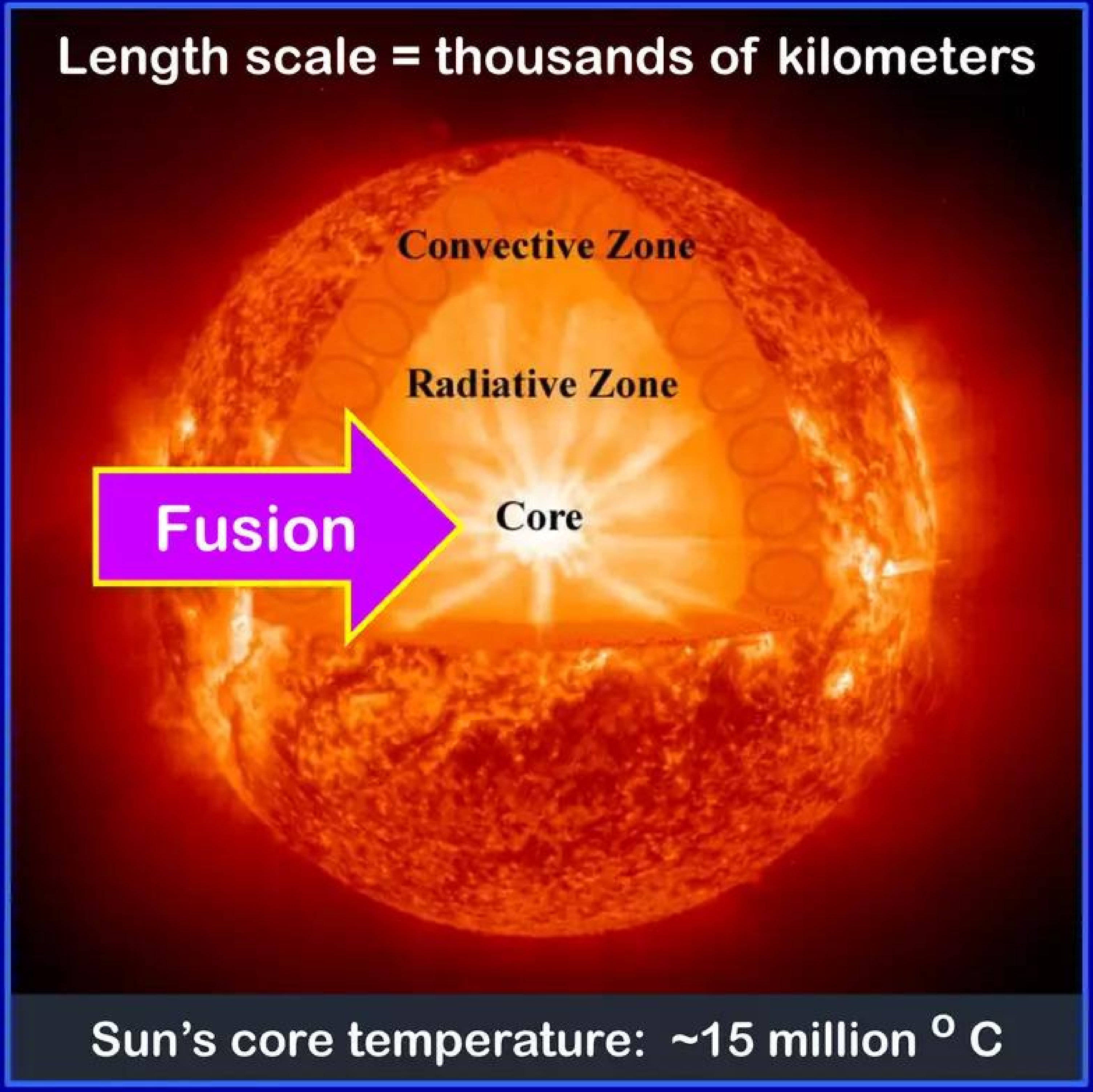
Triggering nuclear fusion processes requires huge temperatures

Stars accomplish this feat using 2-body kinetically driven reactions

Nuclear fusion processes occur primarily in Sun's 15 million degree core

Earth's Sun is a small, long-lived G-type yellow dwarf star: fuses hydrogen in $p^+ + p^+$ reactions





“Normal science” *a la* Kuhn re Deuterium fusion *ca.*1989

Nuclear fusion deemed well-understood as high temp 2-body reactions

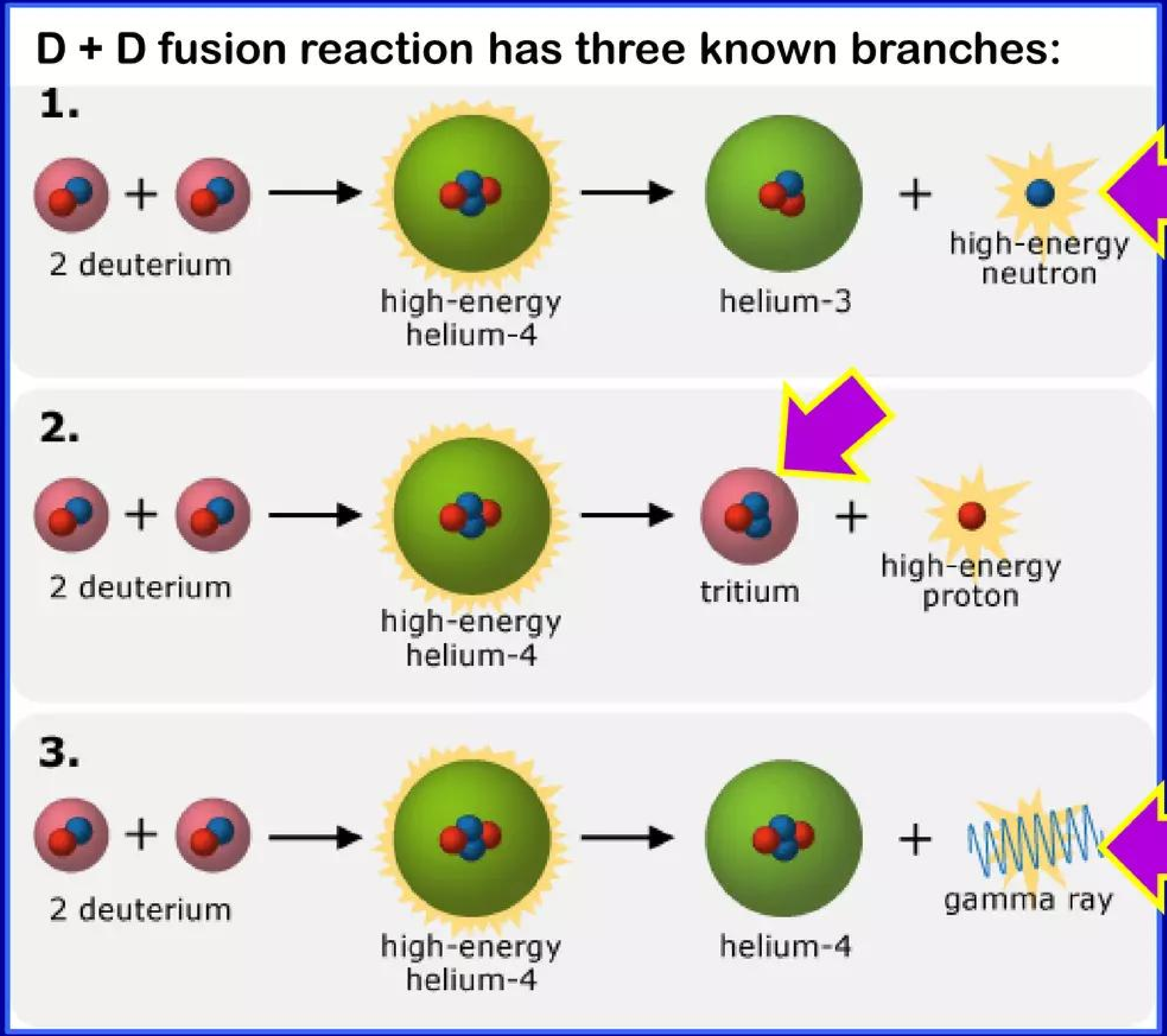
D + D fusion process known to have 3 branches with high MeV-energy products

All known fusion reactions will produce dangerous fluxes of MeV-energy gamma radiation

~50 %

~50 %

~10^{-5} %



Deadly neutron radiation

Tritium is a gaseous radioactive Hydrogen isotope

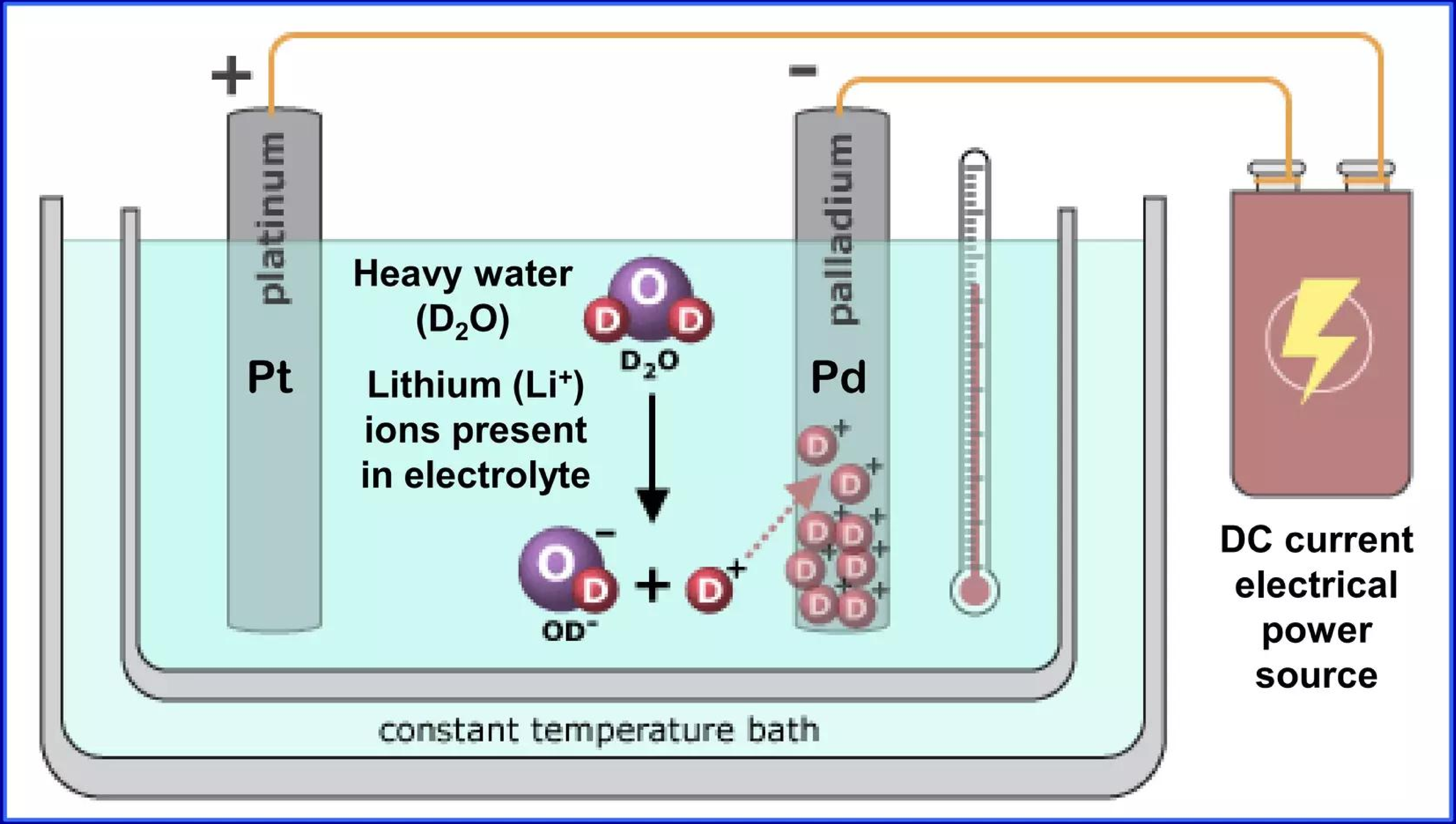
Deadly gamma radiation

Adapted from source: http://undsci.berkeley.edu/article/0_0_0/cold_fusion_04

March 1989: experimental results challenged paradigm

Pons & Fleischmann claim to trigger nuclear reactions in chemical cell

Results occurred in aqueous electrochemical cells akin to battery being charged



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

P&F claimed to see nuclear effects in electrolytic cells

Reported excess heat beyond chemical process & implied Helium-4

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
- ✓ Experiments were more-or-less irreproducible; 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 reports and (now infamous) TV news conference at the University of Utah were rapidly followed by a high-level international meeting of physicists to discuss claims held at the Ettore Majorana Center in Erice (Sicily), Italy

Pons & Fleischmann's paradigm challenge created furor

Participants in intense debate fixated on strong interaction D+D fusion

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

April 12, 1989 meeting, Erice, Italy: physicists agreed that $m_e \rightarrow m_e^*$ could boost D+D rates

- ✓ General agreement that the 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 had been 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 production from chemical cells
- ✓ It was 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 an *ad hoc* 'what if' assumption that effective electron masses were somehow increased inside of a Palladium lattice
- ✓ Koonin & Nauenberg (Univ. California) had 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, added *caveat*, "we know of no plausible mechanism for achieving such enhancements." Walling & Simons (Univ. Utah) soon published a paper with roughly same conclusions

Electron mass-enhancement favorably discussed at Erice

Even so, the calculation of the rate at which deuterium nuclei in a molecule will undergo fusion is important as a yardstick for assessing the rates reported in the recent experiments. At last week's forum, new calculations were presented[3] by S.E. Koonin (Santa Barbara) of the number of fusion reactions per deuteron bound in a deuterium molecule by 'electrons' of normal charge but mass m* instead of m_e. If the logarithm (base 10) of the number of fusions per deuteron per second is λ (with a subscript to indicate the fusion mode), the results come out as follows:

with λ_{dd} of some 10^9 s^{-1}, as predicted[3] and observed[1].

The rate of neutron production claimed by Jones *et al.* is $\lambda_{dd} = 10^{-30}$, which would require that m^*/m_e was equal to 5, according to the figures in the table. A similar value of the effective mass is needed to explain the γ-ray counts reported by Fleischmann and Pons.

Theoretical calculations were published later in:

"Calculated fusion rates in isotopic hydrogen molecules" S. E. Koonin and M. Nauenberg *Nature* 339 pp. 690 - 691 (June 29, 1989)

Electron mass increase factor

	Log$_{10}$ of fusion rate per *d* per second			
m^*/m	1	2	5	10
λ_{dd}	63.5	40.4	19.8	9.1
λ_{pd}	55.0	36.0	19.0	10.4

Others at the meeting agreed with these results, which correct an error in some previous calculations and use a more accurate molecular potential. An important experimental point is provided by the case in which m*=207, corresponding to that in which a negative muon binds two deuterons as a molecular ion 207 times smaller in dimensions than the normal molecular ion,

Screen-captures of text from R. Garwin's report summarizing meeting in Erice, Sicily:

"Consensus on cold fusion still elusive"
R. L. Garwin
***Nature* 338 pp. 616 - 617 (April 20, 1989)**

http://fas.org/rlg/04_20_1989%20Garwin%20NATURE%20Cold_Fusion.pdf

Koonin & Nauenberg's preprint was published in *Nature*

Enhancements of electron mass by factors of 5 - 10 would be required

Abstract:

"Cold fusion occurs when two nuclei with very small relative energy tunnel through their mutual Coulomb barrier to initiate a nuclear reaction. The phenomenon is well studied in muon-catalysed fusion[1–4], where a relatively massive muon replaces an electron in a diatomic molecule of hydrogen isotopes, enhancing the binding and producing cold-fusion rates of $\sim 10^{12}\ s^{-1}$. Cold fusion is also believed to occur as pycnonuclear reactions in certain astrophysical environments[5]. Recent reports of cold fusion between hydrogen isotopes embedded in palladium[6] and titanium[7] have prompted us to reconsider previous estimates of the cold-fusion rates for free diatomic isotopic hydrogen molecules. In particular, we have calculated rates in diatomic hydrogen molecules of various isotopic composition. An accurate Born-Oppenheimer potential was used to calculate the ground-state wave functions. We find that the rate for d + d fusion is $3 \times 10^{-64} s^{-1}$, some 10 orders of magnitude faster than a previous estimate. We also find that the rate for p + d fusion is $10^{-55} s^{-1}$, which is larger than the d + d rate because of the enhanced tunneling in the lighter system. Hypothetical enhancements of the electron mass by factors of 5 - 10 would be required to bring cold-fusion rates into the range of recently claimed observations."

"Calculated fusion rates in isotopic hydrogen molecules" S. E. Koonin and M. Nauenberg
Nature **339** pp. 690 - 691 (June 29, 1989)

http://www.fulviofrisone.com/attachments/article/358/Calculated%20fusion%20rates%20in%20isotopic%20and.pdf

Selected excerpts from Koonin & Nauenberg's *Nature* paper

Screen-captures of text excerpted from paper:

"Calculated fusion rates in isotopic hydrogen molecules" S. E. Koonin and M. Nauenberg *Nature* **339** pp. 690 - 691 (June 29, 1989)

astrophysical environments[5]. Recent reports of cold fusion between hydrogen isotopes embedded in palladium[6] and titanium[7] have prompted us to reconsider previous estimates of the cold-fusion rates for free diatomic isotopic hydrogen molecules. In particular, we have calculated rates in diatomic hydrogen molecules of various isotopic composition. An accurate Born–Oppenheimer potential was used to calculate the ground-state wavefunctions. We find that the rate for d + d fusion is 3×10^{-64} s^{-1}, some 10 orders of magnitude faster than a previous estimate. We also find that the rate for p + d fusion is 10^{-55} s^{-1}, which is larger than the d + d rate because of the enhanced tunnelling in the lighter system. Hypothetical enhancements of the electron mass by factors of 5–10 would be required to bring cold-fusion rates into the range of recently claimed observations.

These calculations of the fusion of hydrogen nuclei embedded in a metal are only approximate. Screening by the electrons modifies the Born–Oppenheimer potential[15]. Moreover, fluctuations present in many-body situations might significantly enhance fusion rates[16], although there are limits to the efficacy of this mechanism in equilibrium conditions[17].

It is interesting to ask by how much the internuclear separation must be decreased to reach the fusion rates claimed in refs 6 and 7. Although the precise answer depends on the details of the internuclear potential, a simple way of quantifying the problem is simply to change the radial scale. This is equivalent to endowing the electron with a larger mass m^* than it actually has, in which case the separation scales as m_e/m^*. (This enhanced mass should not be associated with any physical excitation in a solid material, as only the bare electron is relevant at the short length scales that are important here.) Accurate estimates can be made by numerical integration of the Schrödinger equation (5) with the K–W potential[9,10] as shown in Table 2. For other values of m^* we have found that a very good fit is given by

$$\log_{10} \Lambda = 6.5 + \log_{10}(A/a^3) + 3\log_{10}(\mu/M_n) - 79(\mu/M_n)^{1/2}(m_e/m^*)^{1/2} \qquad (10)$$

where M_n is the nucleon mass and the variation with m^* is that given by equation (9). A mass enhancement of $m^* \approx 5m_e$ would be required to bring the cold-fusion rates into the range claimed in ref. 7. This is 2.5 times larger than the value calculated previously[2,12]. An enhancement of $m^* \approx 10\ m_e$ is required by the results of ref. 6.

It is worth remarking on the validity of the Born–Oppenheimer approximation as used in this context. As there is a large difference between the potential and total energies in the classically forbidden region, one might naively expect a failure of the adiabatic assumption. However, more careful reflection suggests otherwise. Systematic corrections to the adiabatic approxima-

"Hypothetical enhancements of the [effective] electron mass by factors of 5 - 10 would be required to bring cold-fusion rates into the range of recently claimed observations."

a role. We also find that hypothetical enhancements of the electron mass by factors of 5–10 are required to bring cold-fusion rates into the range of values claimed experimentally. However, we know of no plausible mechanism for achieving such enhancements.

Walling & Simons published a similar paper in the *JPC*

Enhancements of electron mass by factors of 10 - 12.5 were required

Screen-capture text represents excerpted first sentence from abstract of *JPC* paper:

We propose that the large energy release reported in the experiments of Fleischmann, Pons, and Hawkins may be the consequence of ^2H fusion accelerated through screening by neighboring "heavy electrons" with mass $m^* \cong 10$ electron masses. The presence

In early April 1989, Koonin & Nauenberg began to circulate a preprint of their paper invoking heavy-mass electrons via fax; it is very likely that Walling & Simons saw it before writing this paper published in *JPC*

The most plausible explanation of the apparent enhanced rate of $^2H + ^2H$ fusion (by a factor of 10^{53} in these experiments) involves a tunneling phenomenon aided by screening of the Coulombic repulsion between the $^2H^+$ ions by the surrounding electron density[3] in the lattice as discussed further below. The conventional

Source of screen-capture text excerpts:

"Two innocent chemists look at cold fusion", C. Walling and J. Simons, *Journal of Physical Chemistry* **93** pp. 4693 - 4696 (June 15, 1989)

http://simons.hec.utah.edu/papers/137.pdf

Reference #3 was earlier theoretical paper by E. R. Harrison (*Proc. Phys. Soc. London* 84 pp. 213 1964) in which the idea of heavy electron masses $m_e^* > m_e$ was introduced to increase an electron screening effect that will decrease the width (but not the energetic height) of the barrier through which quantum mechanical tunneling must occur to accelerate rates of pycnonuclear fusion reactions

As described on p 218 of ref 3, reduction of the Coulombic potential allows the two D^+ nuclei to approach more closely before reaching their classical turning points. This, in turn, requires tunneling through a shorter distance to reach the region where the strong nuclear forces exist. These effects can be modeled in terms of the "binding" together of the two $^2H^+$ ions due to[6–8] "heavy electrons" in the metal. In this model, the collision energy E of the $^2H^+$ pair is viewed as increased by a factor m^* equal to the ratio of the metal's effective electron mass and the bare electron mass: $E^*/E = m^*$. Considering this increase in energy, which yields a speed ratio $v^*/v = m^{*1/2}$, allows the fusion rate expressions to be extended to treat events taking place in the presence of screening for which

$$\log R = 13.6 - 77(\mu^{1/2}/m^{*1/2}) \qquad (5a)$$

or

$$\log R = 10.6 - 74(\mu^{1/2}/m^{*1/2}) \qquad (5b)$$

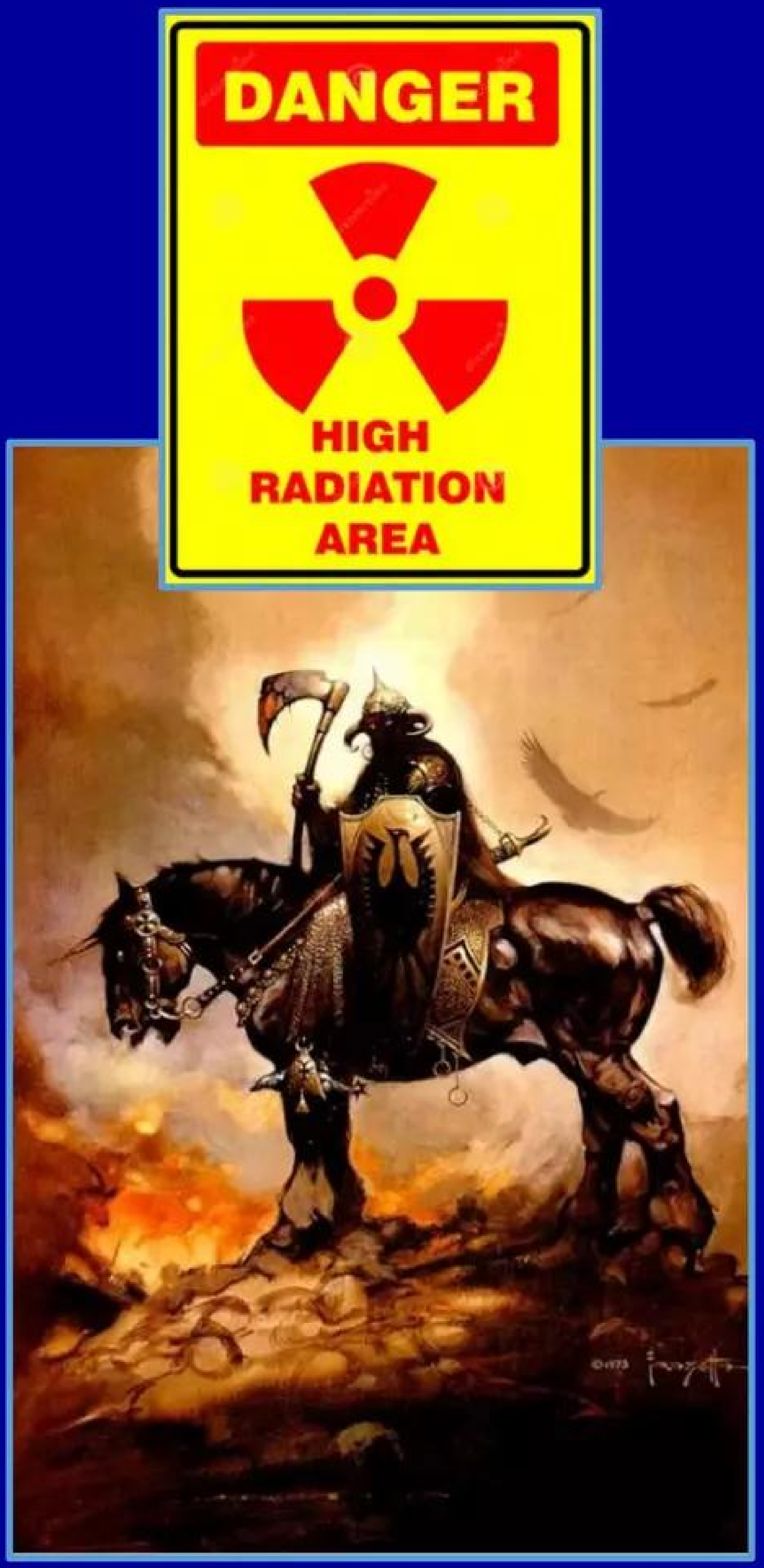
In terms of the model introduced here to interpret cold fusion in deuterium-loaded Pd metal, the rate acceleration required to account for the production of 10 W cm^{-3} requires an effective electron mass of $m^* = 10$ ($m^* = 12.5$ for the second model).

Increased electron masses could explain apparent rates

Absence of MeV-energy gamma and neutron radiation still inexplicable

Observed features of heat-producing reactions didn't fit into any fusion paradigm

- ✓ While increased electron masses could explain the apparent fusion rates, there was no existing theory to create such increases inside a bulk Pd metallic lattice
- ✓ For the most part, everyone was fixated on trying to understand how D+D fusion reactions could work in Pd cathodes; neutrons were not considered to be likely causative agents because: (a) only small, erratic bursts were occasionally detected; and (b) no one seriously considered the possibility of neutrons perhaps being crated *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 gammas



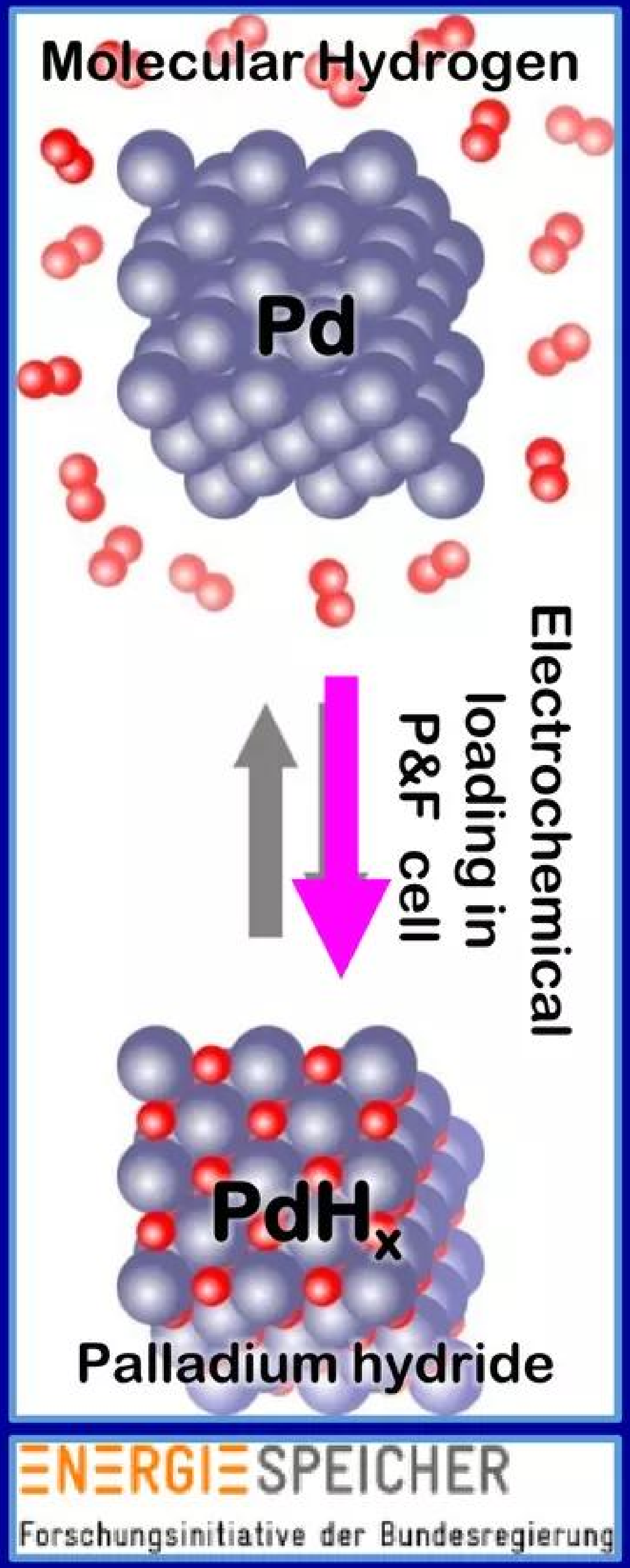
Frank Frazetta
"The Death Dealer" (1973)

Scientists at Erice unaware that LENRs are surface effect

Fixation on idea of D+D fusion in bulk Pd lattice hampered clear thinking

- ✓ Many theoreticians discussing P&F's data were comfortable with idea of heavy-mass metallic conduction electrons; but the physics needed to achieve such mass increases were unclear
- ✓ Near-universally held assumption that LENRs mainly occurred somewhere in the bulk Pd hydride lattice and total fixation on proving or disproving D+D fusion in P&F electrochemical cells hampered clear thinking by theorists; this unfortunate focus prevented most of them from considering other possibilities, such as nuclear processes occurring on Pd cathode surfaces where the Born-Oppenheimer Approximation was well-known to break down and extremely high electric fields of at least 10^9 V/m were known to be present in a Pd cathode's double-layer
- ✓ To our knowledge, in 1989 very few of the prominent physicists then-involved in the "cold fusion" controversy gave any serious consideration to the possibility that *weak interactions* were involved in excess heat production observed on Pd cathodes. Specifically, none *explicitly* speculated that the $e^- + d^+$ or $e^- + p^+$ electroweak reactions perhaps produced neutrons that were captured on Palladium or Lithium on the cathode surface (this still wouldn't explain lack of MeV neutron or gamma radiation)

Hydrogen isotopes enter bulk Pd metal at specific lattice sites as p+ or d+ ions



New Energy Times obtained lost experimental data from 1989

Steven B. Krivit provided copies of report docs to Lattice for evaluation

The Naval Research Laboratory and Lawrence Livermore National Laboratory

NRL and LLNL reported experimental results with P&F-type cells in October 1989

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

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

August 1993

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

Rolison *et al*. looked for products with mass spectroscopy

Conducted all their experiments with P&F-type electrochemical cells

Used sensitive TOF-SIMS to measure Pd isotopes on surfaces of cathodes

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

Rolison *et al*. looked for products with mass spectroscopy

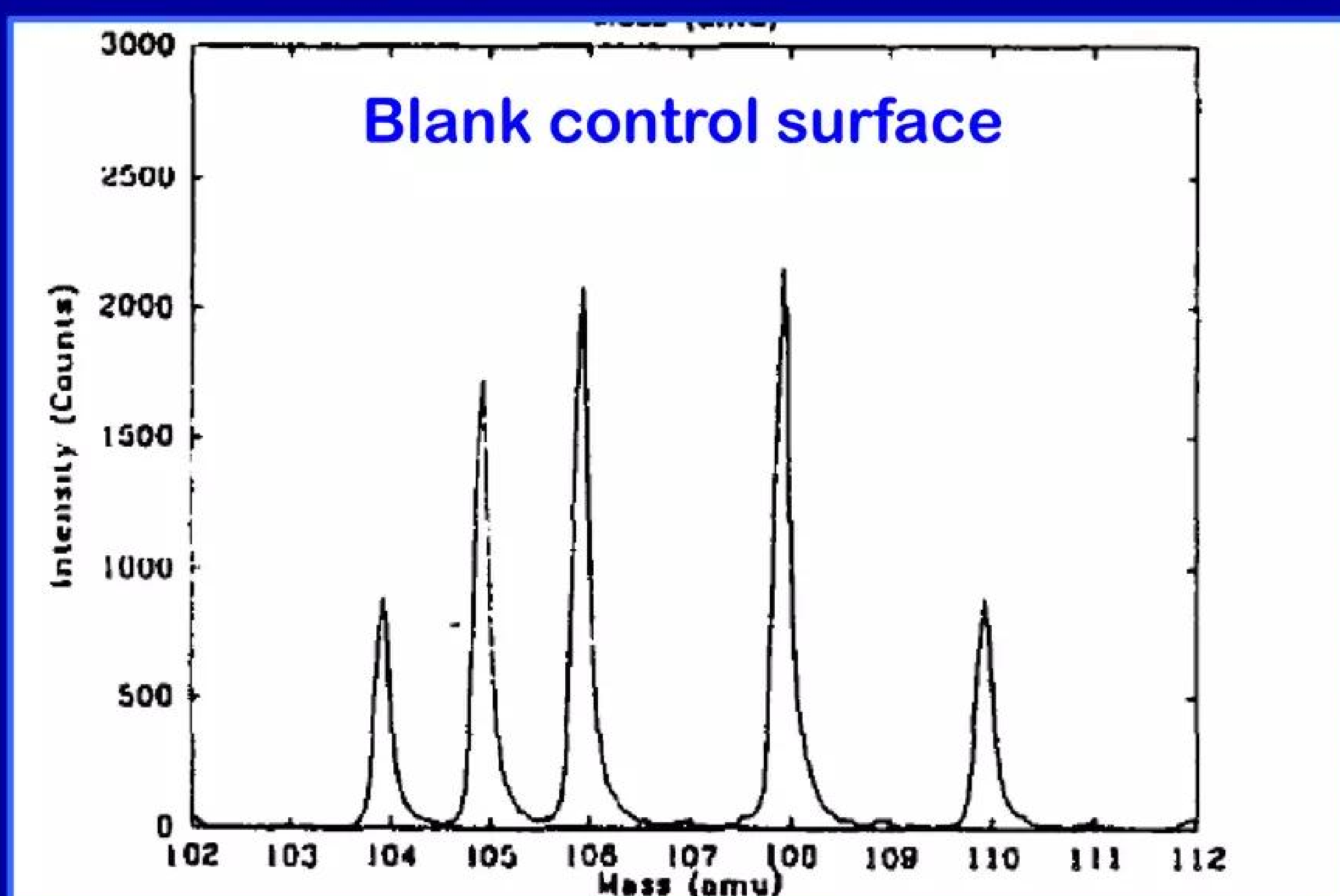
Before-and-after analyses of Pd cathodes showed big isotopic shifts

Palladium isotopic ratios were oddly "scrambled" on surfaces of cathodes

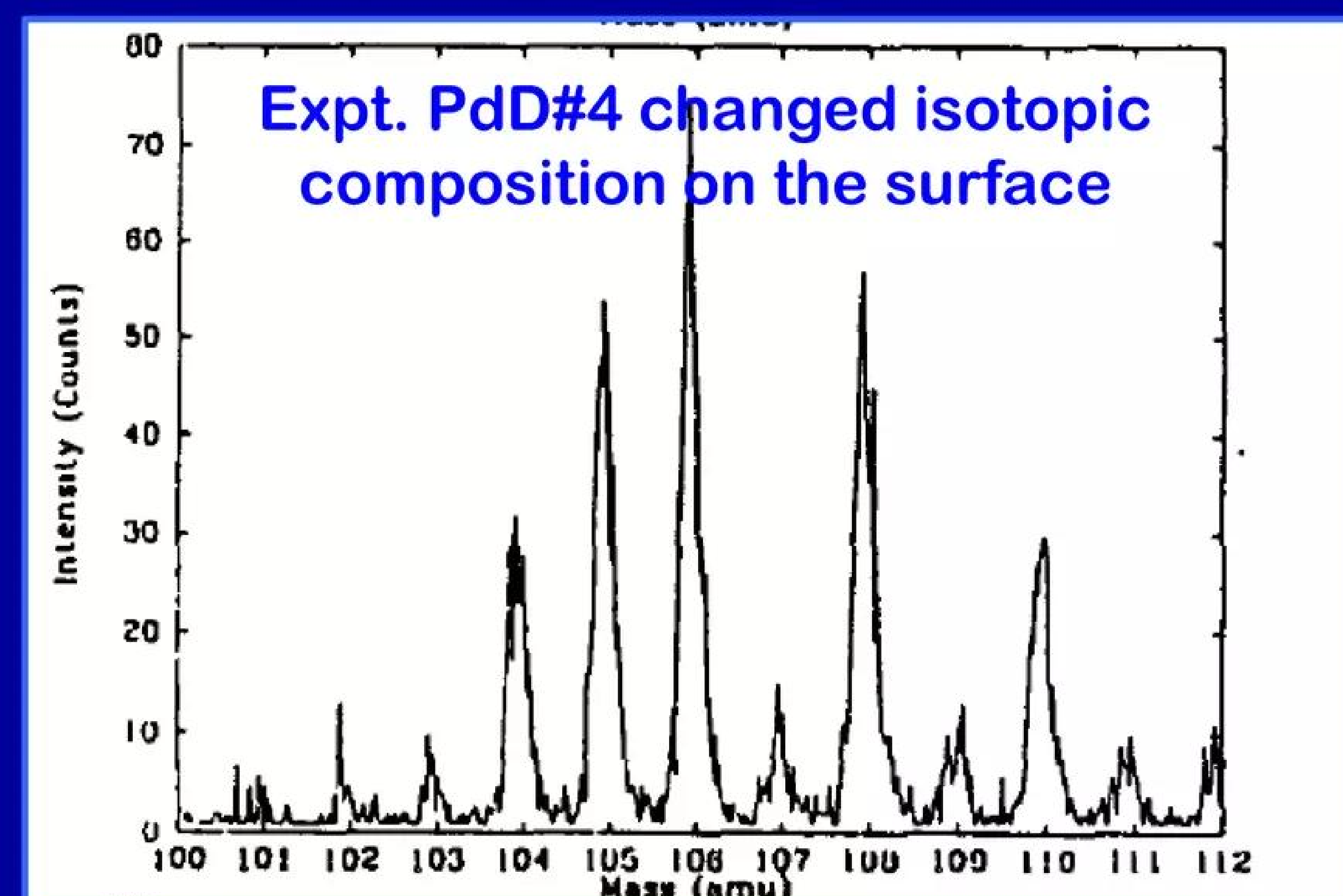
Mass peaks (amu) correspond to intensities (~amounts) of Palladium isotopes

> 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

More from Rolison *et al.*'s EPRI-NSF 1989 Workshop report

Isotope anomaly is near-surface; does not extend into bulk lattice

Experiment PdD#4 had 50%enrichment in Pd-106; Pd-105 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 tne zirconium contamination seen for PdD#10.

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

Discussion of Rolison *et al.*'s EPRI-NSF Workshop report

Observed Pd isotopic shifts could only result from nuclear process

Results are explained by neutron captures on Pd but 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 see 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 same 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 substantial neutron fluxes during their 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

Lawrence Livermore National Lab at the EPRI-NSF Workshop

Edward Teller reported LLNL had seen clear isotopic shifts in Lithium

Stated that Lithium-6 isotope had been depleted on Pd cathode surfaces

Used same basic experimental design with P&F-type D_2O electrochemical cell

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

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 10^6 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

LENRs are a surface phenomenon … not bulk lattice

Different physics possible on surfaces; Born-Oppenheimer breakdown

Electrons and protons are exposed to electric fields $>10^9$ V/m on cathode surfaces

- ✓ In October 1989, U.S. government scientists reported experimental data with P&F-type electrolytic cells which conclusively showed: (1) LENRs are a surface phenomenon; and (2) measured shifts in Palladium and Lithium isotopes that were fully consistent with low-energy neutron captures; still left with puzzling lack of deadly neutron and prompt gamma radiation
- ✓ Born-Oppenheimer Approximation was well-known to break down at surfaces and interfaces; opens-up the possibility of creating very high local electric fields
- ✓ In 1989, well-known that local electric fields in double-layer on Pd cathode surface could be $> 10^9$ V/m; now known that 30-nanosec pulsed E-fields at tips of sharp asperities on such surfaces can briefly hit $> 10^{12}$ V/m*
- ✓ Huge electric fields on metal cathode surfaces in P&F D_2O or H_2O electrochemical cells creates high local molecular ionization at cathode/electrolyte interface: electrons and protons are thus present on surfaces

High electric field at surface of P&F chemical cell cathode; Q-M model of double-layer

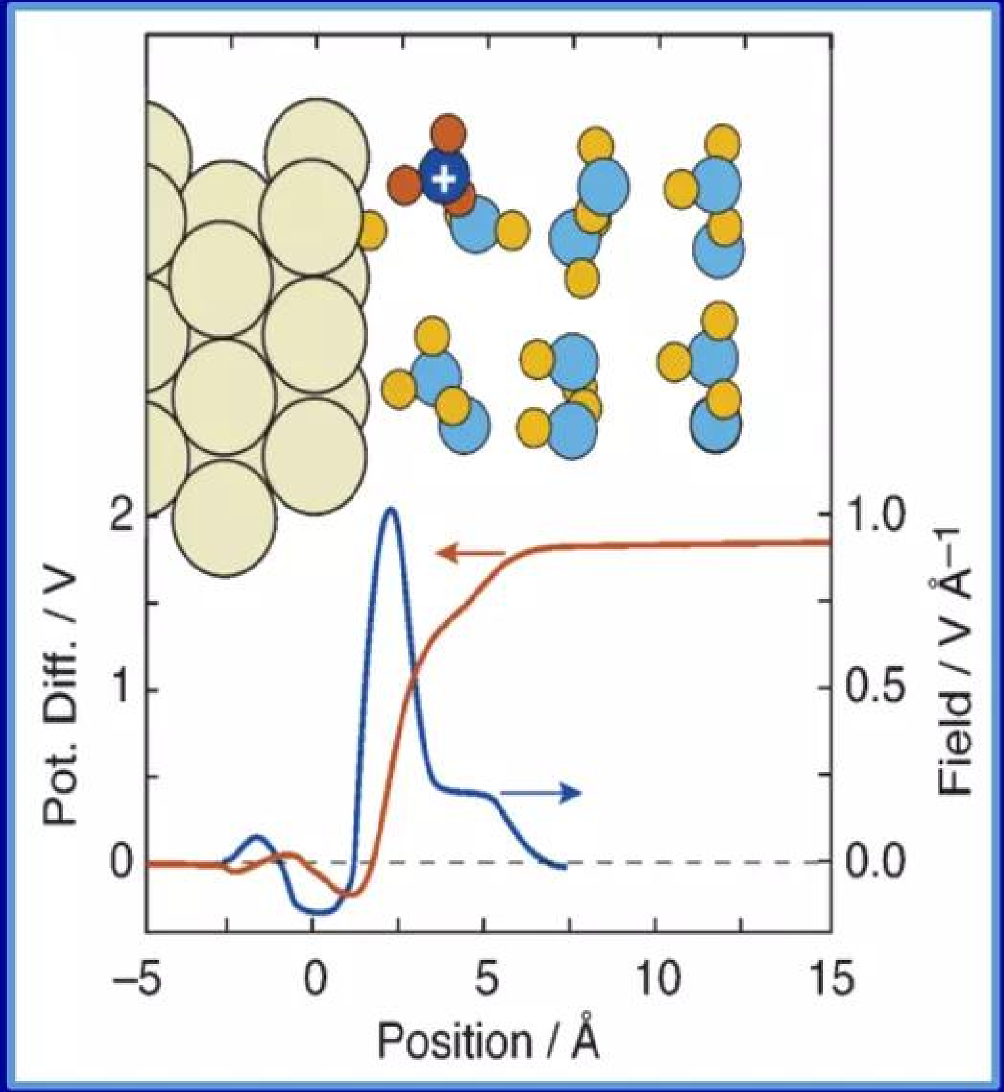


Fig. 2. DFT/molecular dynamics simulation of a charged Pt(111) slab with 3 water layers and 1 solvated hydronium ion. Adapted from J. Rossmeisl *et al.*, "Modeling the electrified solid-liquid interface," *Chemical Physics Letters* 466 pp. 68 - 71 (2008)

http://faculty.washington.edu/stuve/fi_water.htm

In 1989 neutron production in P&F cells seemed unlikely

Energy barrier for *e* + *p* electroweak reactions thought insurmountable

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 ~ 1.18×10^{-44}/cm^2 [source: H. Bethe]

- ✓ Unfortunately, 782 keV 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

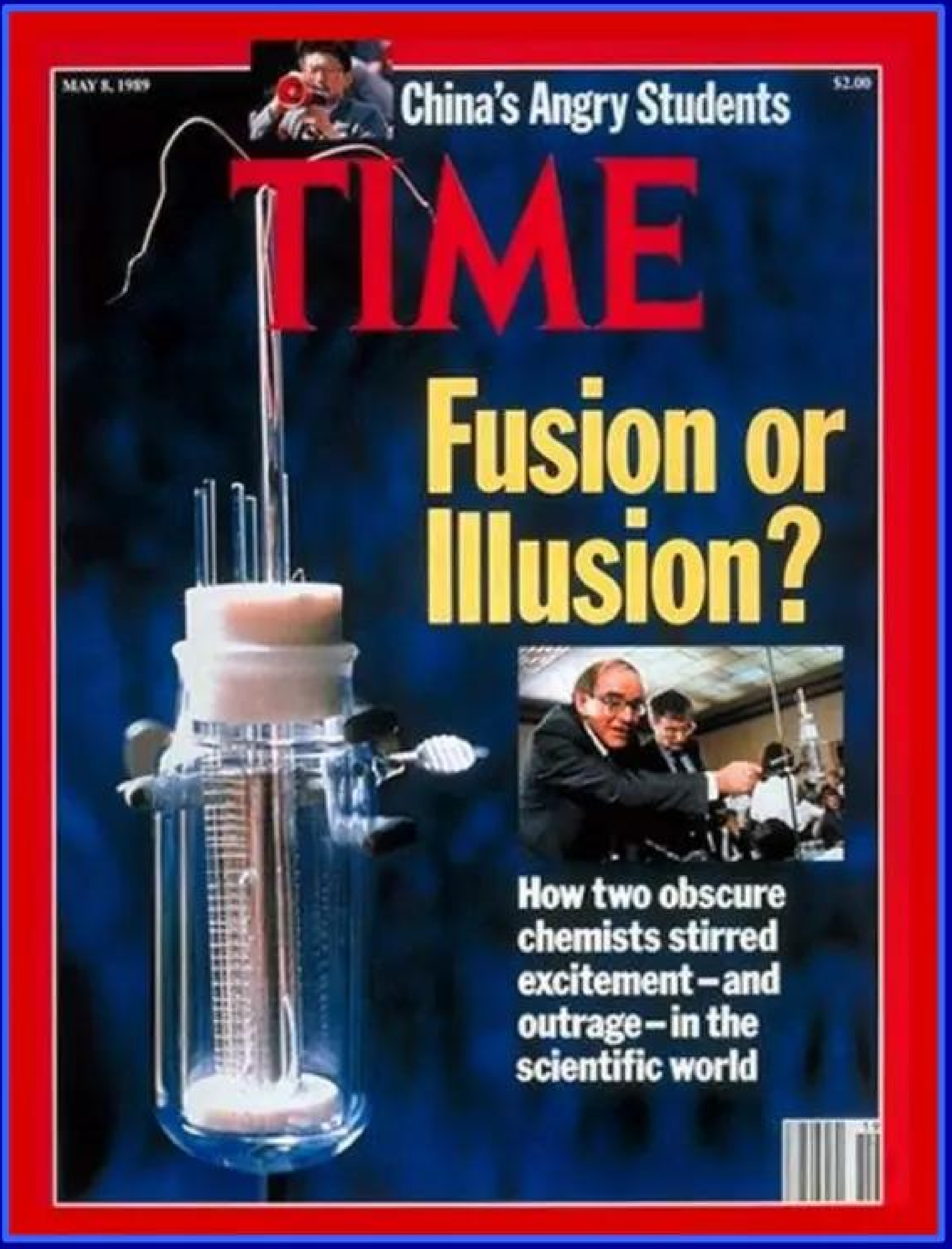
- ✓ Answer to this conundrum finally provided by Widom & Larsen 16 years later in 2005 by invoking many-body collective effects along with quantum entanglement of charged particles (SP electrons and protons or deuterons) in condensed matter

P&F-type experimental results inconsistent with fusion

Key issue along with irreproducibility doomed Pons & Fleischmann

By late 1989 results discredited and presumed to arise from experimental error

- ✓ Supposed D+D fusion in electrochemical cells, as envisioned by Pons & Fleischmann, was really just a fevered scientific illusion unsupported by data
- ✓ However, 26 years later we now know that while P&F's theorized room temperature "cold fusion" mechanism was totally erroneous, their excess heat measurements were likely correct and they probably really did produce some Helium-4
- ✓ Thanks to the Widom-Larsen theory, we can now understand and explain all of P&F's curious 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; this data was lost in acrimonious controversy about fusion



Time Magazine May 8, 1989

1996-97: some Japanese thought neutrons behind LENRs

Convinced by mass spectroscopy data but couldn't explain the physics

Researchers observed transmutation products without any concurrent radiation

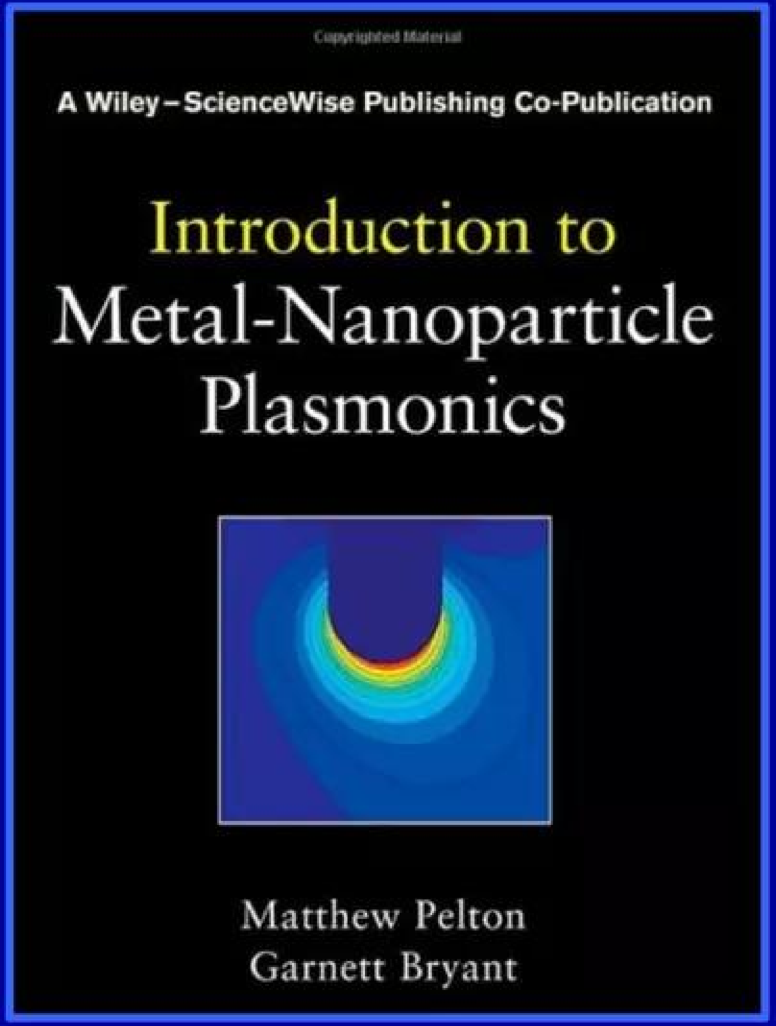
- ✓ By 1996 - 1997, some Japanese researchers (notably Iwamura *et al.* at Mitsubishi Heavy Industries, T. Mizuno at Hokkaido Univ., and H. Kozima) had become convinced by mass spectroscopy data that neutrons were key causative factors in LENRs. In his 1997 book, T. Mizuno explicitly speculated that the $e + p$ reaction produced such neutrons. However, these researchers were unable to articulate rigorous physics that could produce neutrons *in situ* at significant reaction rates; neither could they explain the utterly baffling experimental absence of large, readily detectable fluxes of energetic MeV-energy neutrons and capture gammas

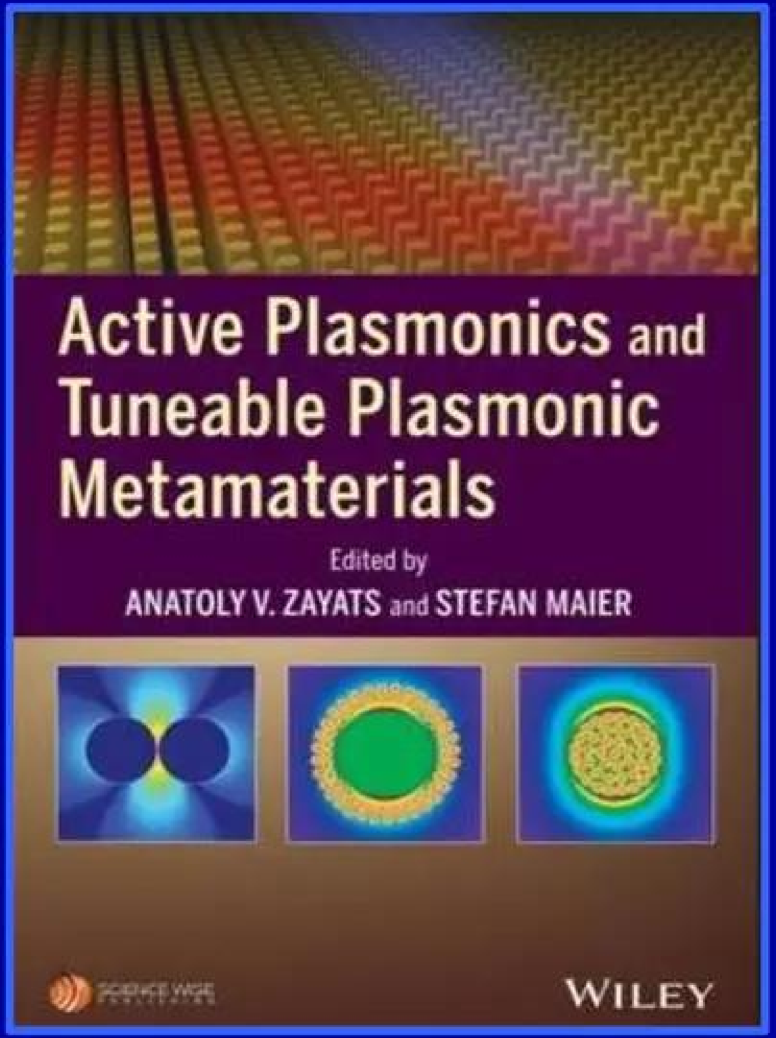
- ✓ In 1996 G. Miley *et al.* of University of Illinois at Urbana-Champaign conducted multi-week experiments using light-water Li_2SO_4 Pt/Ni P&F-type electrochemical cells and performed a wide variety of different types of post-experiment mass spectroscopy analyses on the reacted Nickel cathodes. Observed an amazingly large array of nuclear transmutation products with atomic masses ranging from A = 4 out to A > 200. When measured production rate data from all experiments was plotted against values of A, the graph revealed a very complex 5-peak mass spectrum. Miley *et al.* interpreted this feature as resulting from the fission of unstable superheavy compound nuclei. In 2006, Widom & Larsen were able to successfully reinterpret this weird product mass spectrum as a unique signature 'fingerprint' of the capture of ultralow momentum neutrons on atomic nuclei

Electroweak nuclear catalysis illuminated by other fields

Advances in plasmonics and Q-M entanglement enable W-L breakthrough

- ✓ 1996-97: Mitsubishi and Miley *et al.* did post-experiment SIMS depth-profiling of transmutation products on many cathode surfaces; like Rolison *et al.* in 1989-90, found that transmutations generally did not extend deeper than ~2,000 Angstroms into bulk metal: data clearly showed LENRs most likely a surface effect
- ✓ If that were true, and if electroweak $e^- + d^+$ or $e^- + p^+$ reactions were creating neutrons, what types of electrons were involved in the reactions? Are inner K-shell electron captures being somehow induced inside atomic nuclei located on surfaces? Or are surface plasmon (SP) electrons, well-known to be present on metallic surfaces or at interfaces, reacting directly with p^+ or d^+ ?
- ✓ An accidental experimental discovery in Fall of 2000 answered this key question. Two collaborating LENR researchers, D. Letts and D. Cravens, were experimenting with a D_2O P&F-type Pt/Pd electrochemical cell in which Pd cathode had been electroplated with a thin layer of Gold (Au). During electrolysis they irradiated Pd/Au cathode with 30 milliwatt (mW) 661.5 nm pen laser to see what would happen. To their surprise, calorimetrically measured excess heat increased by 500 mW (>10x the added input energy). Effect repeated at other labs. Well-known that SP electrons are easily excited on Au; experiments thus implicated SPs in LENRs





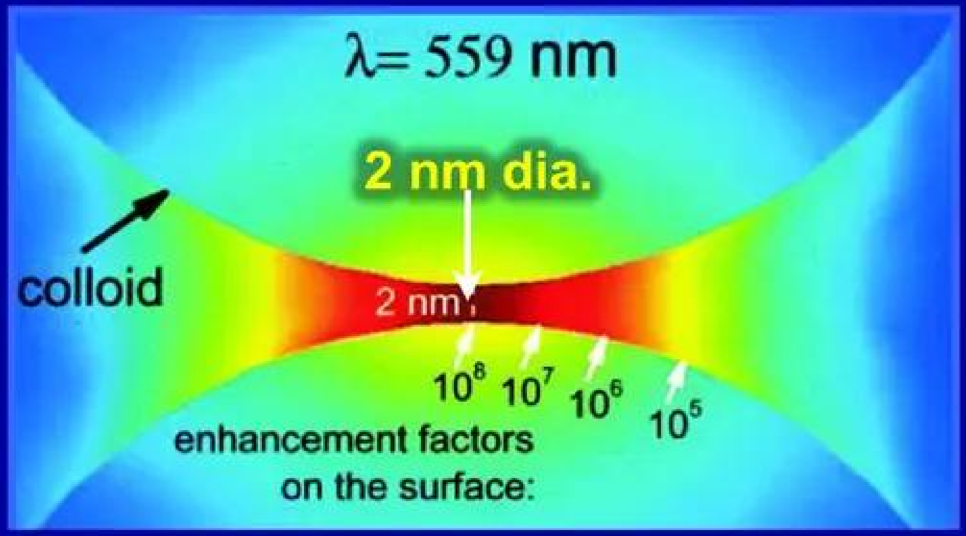
Published by Wiley (2013)

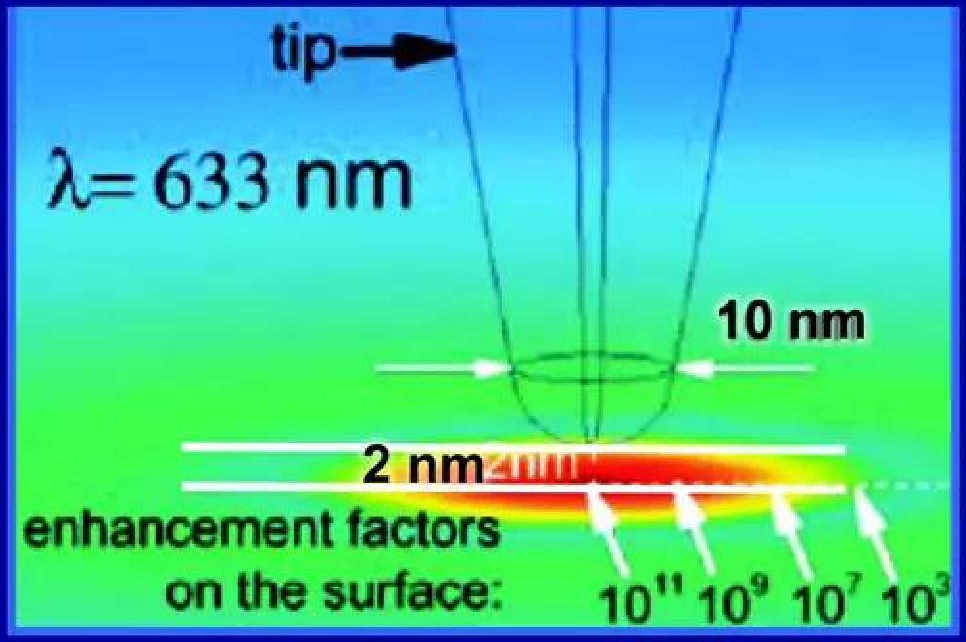
Electroweak nuclear catalysis illuminated by other fields

Advances in plasmonics and Q-M entanglement enable W-L breakthrough

- ✓ At 1989 EPRI-NSF workshop, very prominent nuclear physicist made a prophetic comment "… it would help if we postulated that the nuclei can interact at 10^4 nuclear radii [1.5 μ - microns] and the interaction is not thru tunneling but some exchange of 'particles' which can extend outside of the nucleus."
- ✓ Physicist's prescient ideation about the mechanisms enabling LENRs was realized in form of mutual quantum entanglement of electromagnetically interacting SP electrons, protons, and deuterons on surfaces and at interfaces; provides big spatial domains of interaction amongst entangled nuclei out to >100 μ
- ✓ Conceptually, protons, deuterons, or tritons on surfaces can be viewed as atomic nuclei; many-body collective effects and quantum entanglement enable nm- to >> μ-range interactions amongst them; meet above criteria articulated at EPRI-NSF
- ✓ Starting in mid-1990s Chatzidimitriou-Dreismann (TU Berlin) and others experimentally established that hydrogen atoms on surfaces are quantum mechanically entangled with each other and oscillate collectively. In parallel with that, other workers established that surface plasmons are mutually Q-M entangled and oscillate collectively. These sets of properties were to later become crucial linchpins in the Widom-Larsen theory of LENRs

Huge enhancements of E-field strengths on nm length-scales





"Prospects for plasmonic hot spots in single molecule SERS towards the chemical imaging of live cells"
D. Radziuk & H. Moehwald
Physical Chemistry Chemical Physics
DOI: 10.1039/C4CP04946B (2015)

http://pubs.rsc.org/en/content/articlepdf/2015/cp/c4cp04946b

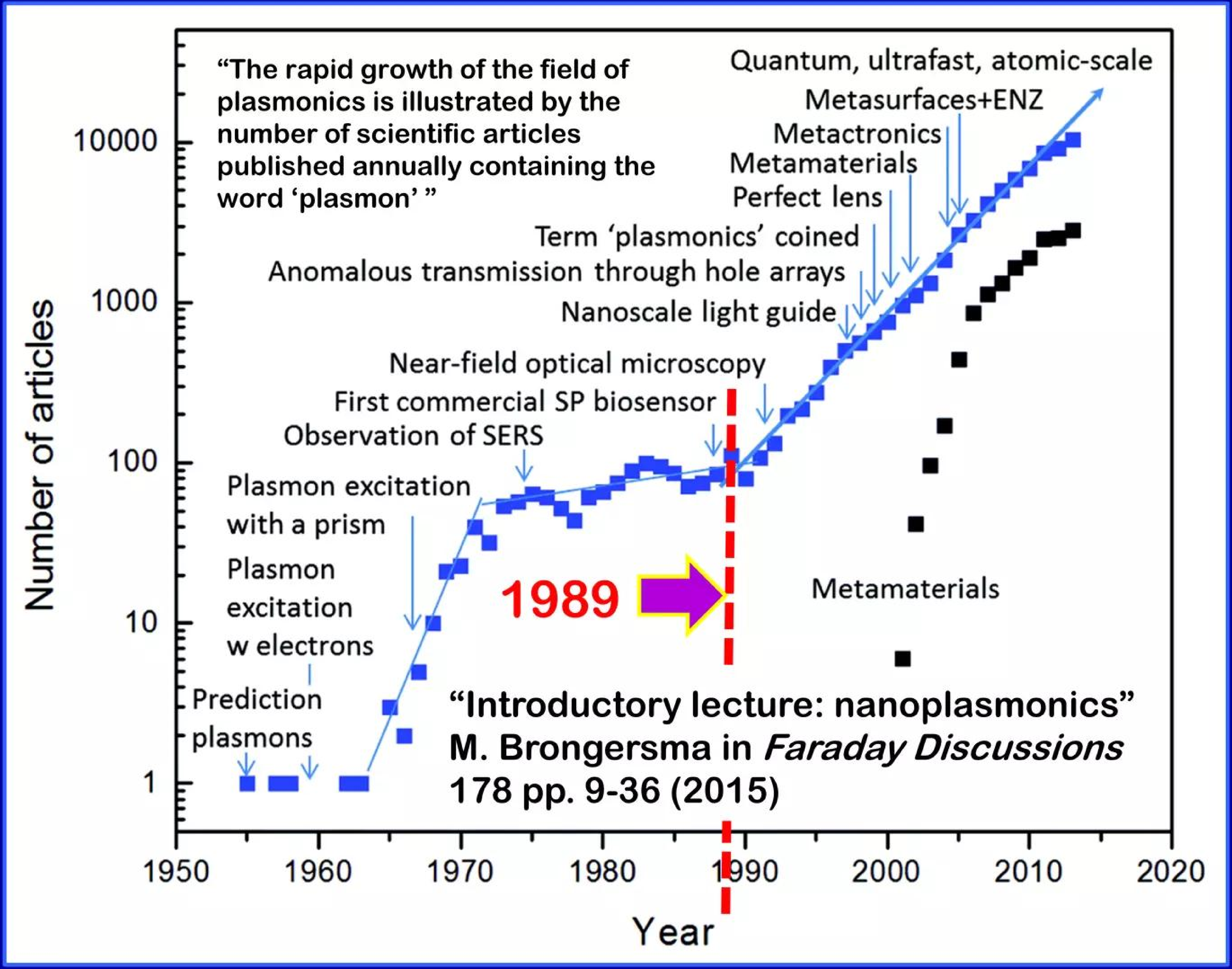
LENRs are an incredibly interdisciplinary area of science

Nanotechnology, plasmonics, and LENRs are presently joined at the hip

- ✓ Like nanotech, LENRs occur in a vast parameter space that intersects and can benefit from knowledge in many different disciplines that include chemistry; solid-state, surface, and nuclear physics; advanced materials science; plasmonics; and so forth
- ✓ Interdisciplinary condensed matter LENRs, plasmonics, and nanotechnology are therefore effectively joined at the hip; collective, many body classical, and coherent quantum mechanical effects are crucial in all these 21^{st} century technologies that have expanded and grown enormously since 1989 when P&F challenged paradigms
- ✓ It should be noted that today's technical knowledge in these fields did not even *exist* in 1989, or even in mid-to-late 1990s. In Lattice's view, condensed matter LENRs have become potentially reproducible only in the past several years. Commercialization may now finally be feasible, thanks to key experimental and engineering guidance provided by the Widom-Larsen theory and its unpublished, proprietary extensions
- ✓ Presently, LENRs can reach temperatures of 4,000 - 6,000^{o} K and boil metals in small numbers of microscopic LENR-active hot spot sites on laboratory device surfaces. Commercialization requires control of key operating parameters, especially achieving very high local surface E-fields on specific types of purpose-designed nanoparticulate structures which have dimensions ranging from nm to μ that can be fabricated using off-the-shelf nanotech processes and then deliberately emplaced at what will become microscopic LENR-active sites on Hydrogen-loaded substrate surfaces

Plasmonics as we know it today grew greatly from 1989

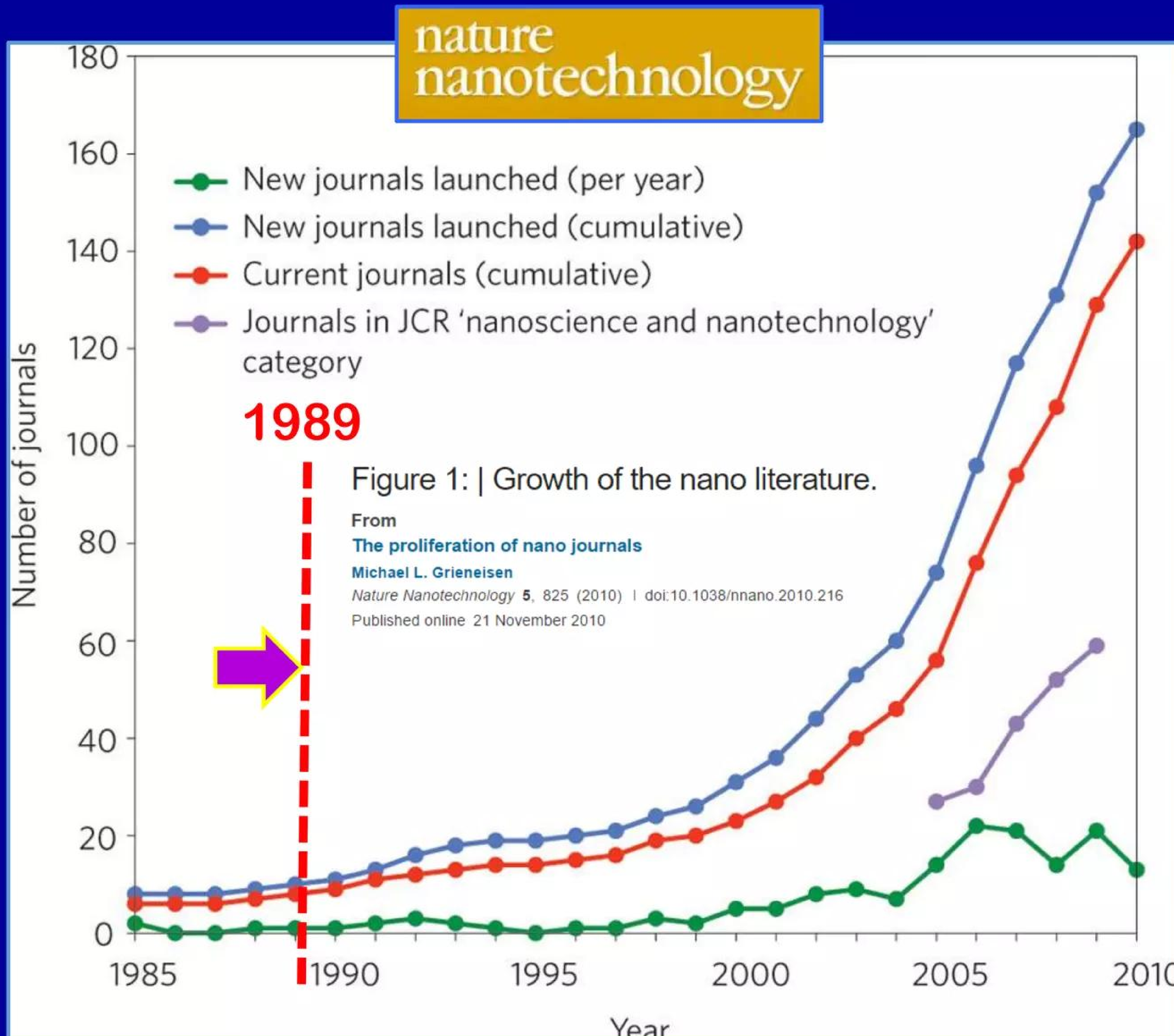
Parallel growth in publications and understanding of Q-M entanglement



http://pubs.rsc.org/en/content/articlelanding/2015/fd/c5fd90020d#!divAbstract

Nanotechnology as it is today grew greatly from 1989

Nanotech and plasmonics crucial to fabrication of LENR-based devices

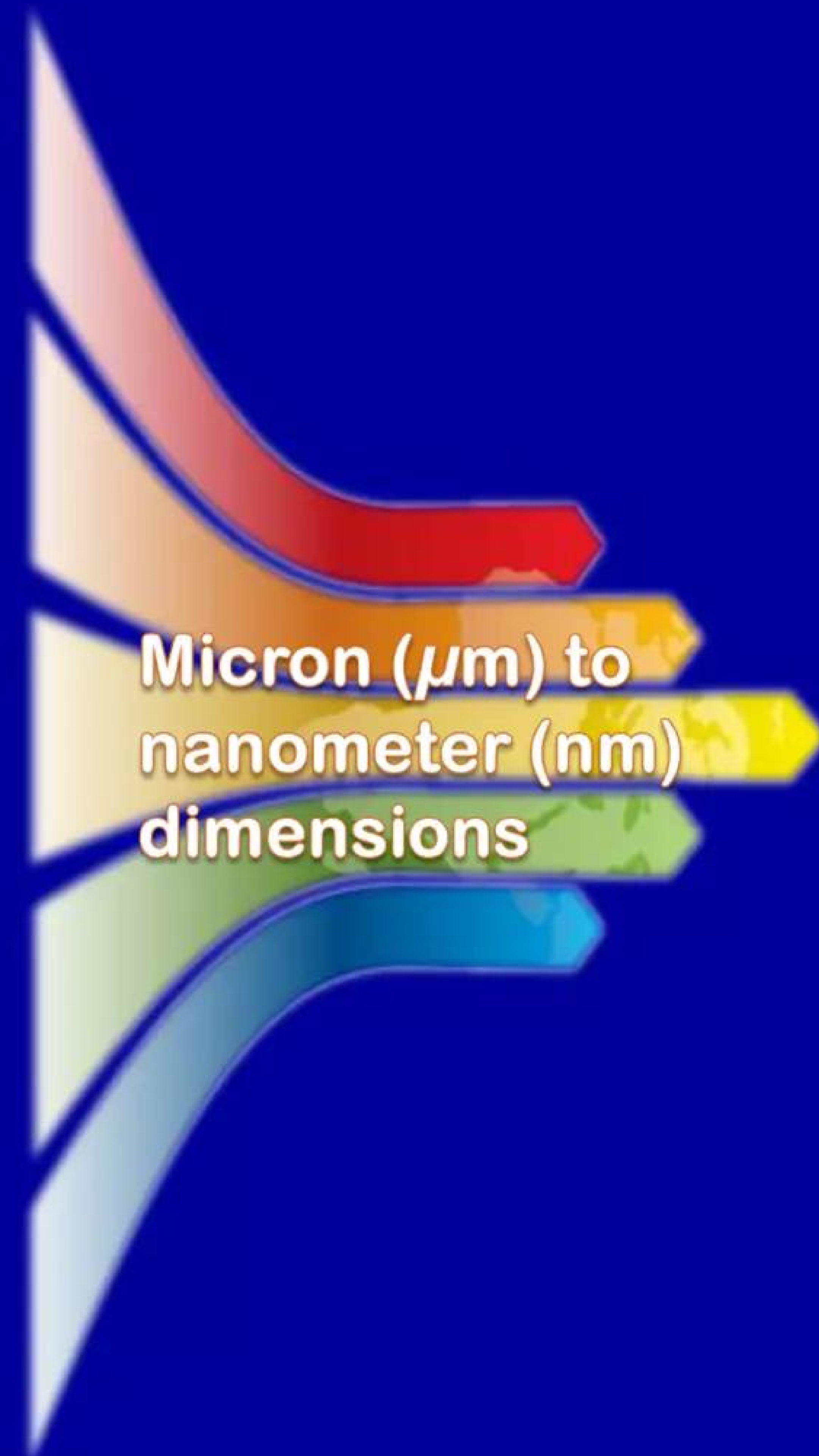


LENRs are an incredibly interdisciplinary area of science

Resisted understanding until Widom-Larsen able to put pieces together

Nanometer-to-micron scale many-body collective effects enable 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



Widom-Larsen theory of LENRS and related areas of science and technology in condensed matter systems utilize crucial knowledge derived from all of these varied disciplines

Nanotechnology, plasmonics, and LENRs joined at the hip

Large length scales

What was formerly thought impossible becomes possible by utilizing applied nanotechnology and plasmonics

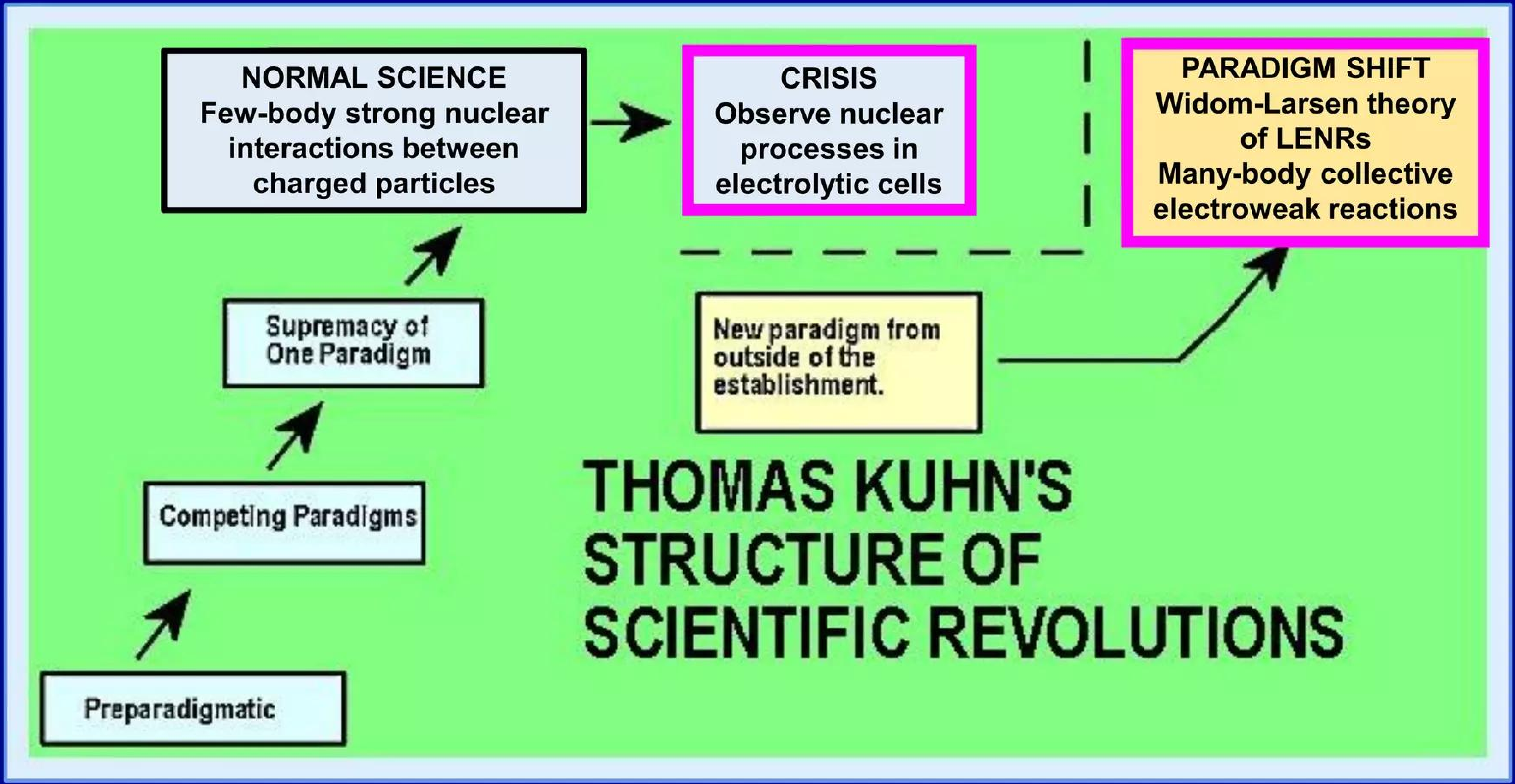
Nuclear-strength electric fields in μ-sized LENR-active sites enable e + p reaction

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

Widom-Larsen 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

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 to work of 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; is the only theory able to explain Prof. John Huizenga's "three miracles" discussed in his highly critical 1993 book on this subject matter
- ✓ W-L theoretical work involves Standard Model interactions and many-body collective Q-M 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

Neutronization reaction's energetics and cross-section

Electroweak production of neutron and neutrino via $e^- + p^+ \rightarrow n^0 + v_e$

In a supernova explosion protons able to react directly with electrons → neutrons

- ✓ Reaction is endothermic; requires input energy of at least 0.78 MeV or 780,000 electron Volts (eV) to have enough energy to produce neutron and neutrino photon
- ✓ Put another way: the rest mass of a neutron is larger than the combined rest masses of an electron and a proton by 0.78 MeV ($m = E/c^2$); this "mass deficit" problem must be overcome for an electroweak reaction to go forward to completion
- ✓ To drive this 2-body reaction relying on just temperature, kinetic energies of charged particles, and the high-energy 'tail' of the Maxwell-Boltzmann distribution, the local environment of free protons and electrons undergoing this reaction must be at a temperature of at least 9×10^9 °Kelvin or roughly, 10 billion degrees
- ✓ Fred Hoyle was the first theorist who conjectured this reaction as the mechanism responsible for producing neutron stars during supernova explosions (1946)
- ✓ For a free proton at rest, the cross-section for a spontaneous reaction with a nearby free electron to make a neutron and a neutrino is $1.18 \times 10^{-44}/cm^2$ (pp. 511 in H. Bethe, "Selected works of Hans A. Bethe: With commentary," World Scientific Publishing 1997); i.e., $e^- + p^+ \rightarrow n + v$ is very unlikely to occur at room temperature
- ✓ Tiny $10^{-44}/cm^2$ cross-section for spontaneous $e^- + p^+$ reactions in condensed matter is fortuitous; otherwise much of the Universe might be an inchoate sea of neutrons

Electroweak reaction cross-sections in supernovas

Nasu *et al.*'s calculated cross-sections still modest at billions of ^{o}K

Two neutrons are produced when electron reacts with deuteron instead of proton

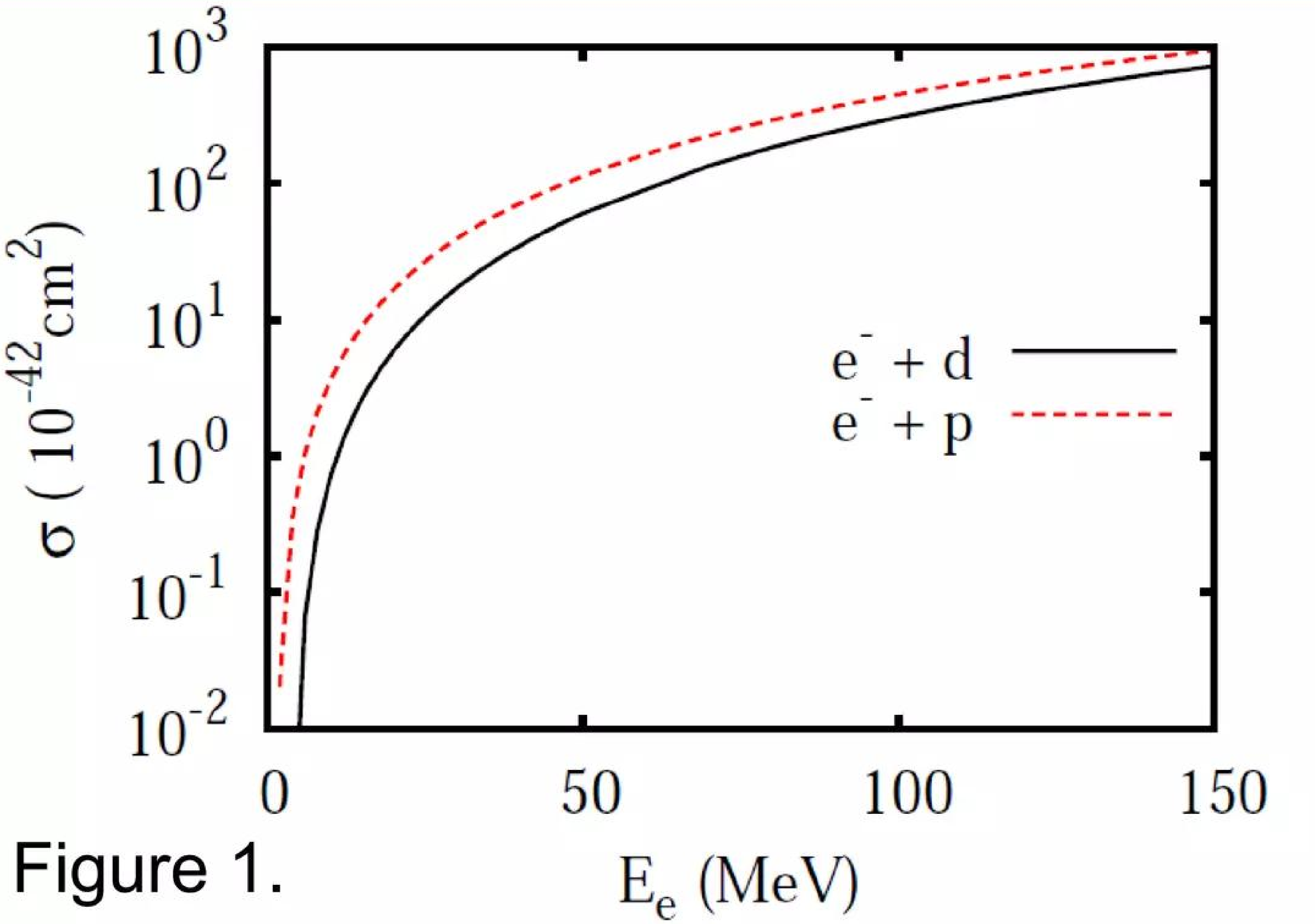


Figure 1.

"Neutrino emissivities from deuteron-breakup and formation in supernovae"
S. Nasu *et al.*, *The Astrophysical Journal* 801 78. doi:10.1088/0004-637X/801/2/78 (2015)

http://arxiv.org/pdf/1402.0959.pdf

W-L rigorously explain the physics of *e** mass increase

Answer key issue posed by Koonin & Nauenberg in 1989 *Nature* paper

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

Electron mass increase needed for p^+ is > 2.53 ; d^+ is > 6.88

It is very well-known that a proton p^+ can capture a charged lepton l^- and produce a neutron and a neutrino from the resulting process [1]

$$l^- + p^+ \to n + \nu_l \,. \qquad (1)$$

A common form of nuclear transmutation in condensed matter is understood in terms of (1). An electron e^- that wanders into a nucleus with Z protons and $N = A - Z$ neutrons can be captured, producing an electron neutrino ν_e and leaving behind a nucleus with $Z-1$ protons and $N + 1 = A - (Z-1)$ neutrons. The electron capture process in a condensed matter nucleus may be described by the nuclear transmutation reaction [2, 3]

$$e^- + (A, Z) \to (A, Z-1) + \nu_e \,. \qquad (2)$$

For (1) to spontaneously occur it is required that the lepton mass obey a threshold condition,

$$M_l c^2 > M_n c^2 - M_p c^2 \approx 1.293\,\mathrm{MeV} \approx 2.531 M_e c^2 \,, \qquad (3)$$

which holds true by a large margin for the muon, but is certainly not true for the vacuum mass of the electron. On the other hand, the electron mass in condensed matter can be modified by local electromagnetic field fluctuations.

ing lengths. (ii) The above arguments can be extended to heavy hydrogen $(e^- p^+ n) \equiv (e^- d^+) \equiv D$, wherein the neutron producing heavy electron capture has the threshold electron mass enhancement

$$\frac{\tilde{M}'_e}{M_e} = \beta'(D \to n + n + \nu_e) > 6.88 \,. \qquad (29)$$

If the field fluctuations average to zero $\overline{A_\mu} = 0$, then the remaining mean square fluctuations can on average add mass to the electron $M_e \to \tilde{M}_e$ according to a previously established rule [7, 8]

$$-\tilde{p}_\mu \tilde{p}^\mu = \tilde{M}_e^2 c^2 = M_e^2 c^2 + \left(\frac{e}{c}\right)^2 \overline{A^\mu A_\mu} \,. \qquad (5)$$

For example, laser light fields can "dress" an electron in a non-perturbation theoretical fashion with an additional mass as in (5). Such mass modifications must be applied to electrons and positrons when pairs can in principle be blasted out of the vacuum [9, 10] employing colliding laser beams. The mass growth in the theory appears in a classic treatise on quantum electrodynamics [8].

Reach value of $e^* \approx 20.6$ on PdH_x cathode surface

From (16), (19), (25) and (26) follows the electron mass enhancement

$$\beta \approx 20.6 \quad \text{(palladium hydride surface)} \,. \qquad (27)$$

The threshold criteria derived from (6) is satisfied. On palladium, surface protons can capture a heavy electron producing an ultra low momentum neutron plus a neutrino; i.e.

$$(e^- p^+) \equiv H \to n + \nu_e \,. \qquad (28)$$

Several comments are worthy of note: (i) The collective proton motions for a completed hydrogen monolayer on the palladium surface require a loose coupling between electronic surface plasma modes and the proton oscillation modes. The often assumed Born–Oppenheimer approximation is thereby violated. This is in fact the usual

Widom-Larsen theory of low energy neutron reactions

Three key publications that begin in March 2006 are referenced below

Many-body collective effects enable electroweak catalysis in condensed matter

"Ultra low momentum neutron catalyzed nuclear reactions on metallic hydride surfaces" Rigorously explains $e + p$ reaction in condensed matter
A. Widom and L. Larsen
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

"Theoretical Standard Model rates of proton to neutron conversions near metallic hydride surfaces" Reaction rate calculations agree with experiments
A. Widom and L. Larsen
Cornell physics preprint arXiv:nucl-th/0608059v2 12 pages (2007)

http://arxiv.org/pdf/nucl-th/0608059v2.pdf

"A primer for electro-weak induced low energy nuclear reactions"
Y. Srivastava, A. Widom, and L. Larsen Summary of W-L theory to date
Pramana - Journal of Physics 75 pp. 617 - 637 (2010)

http://www.ias.ac.in/pramana/v75/p617/fulltext.pdf

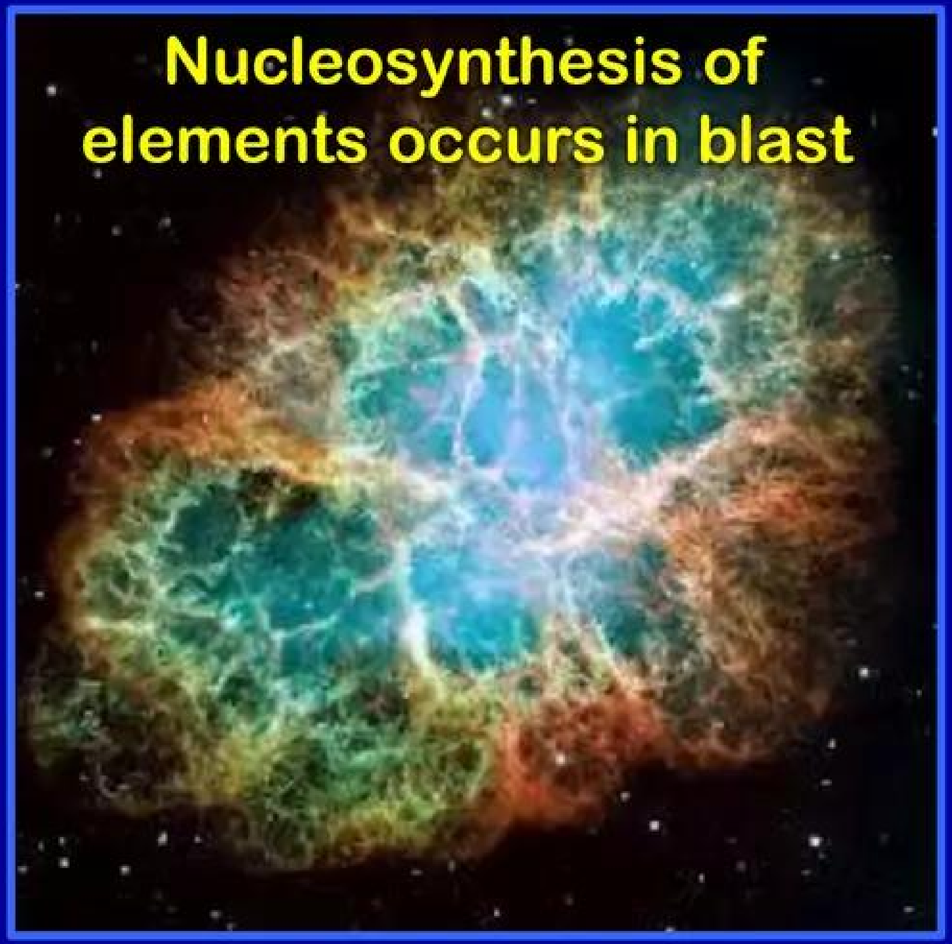
Two-body $e + p$ reaction vs. many-body electroweak catalysis

In stars $e^- + p^+ \rightarrow n + \nu_e$ requires gigantic temperatures and pressures

Unlike stars, LENRs don't need multi-billion-degree temps to trigger $e^- + p^+$ reaction

In stellar supernova explosions $e + p$ neutronization begins at temperature of ~ 9×10^9 °Kelvin

Young neutron star in center



Crab nebula: remnant of a supernova explosion that was observed by many Chinese astronomers in 1054 A.D.

The Crab Pulsar (PSR B0531+21) is a relatively young neutron star at the center of the Crab nebula; it rotates very rapidly and is ~20 kilometers in diameter

Neutronization ($e + p$ reaction) in a supernova

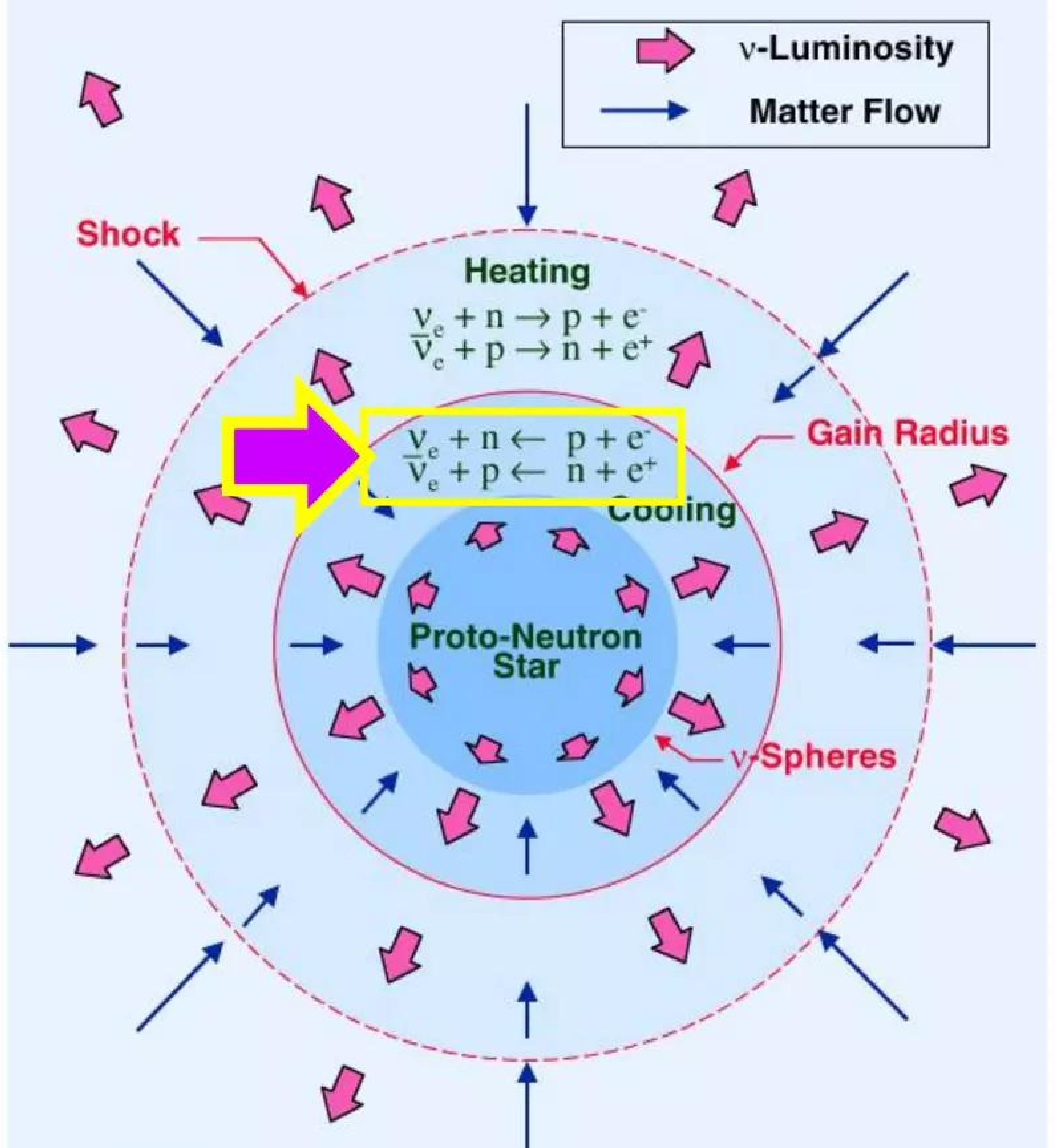
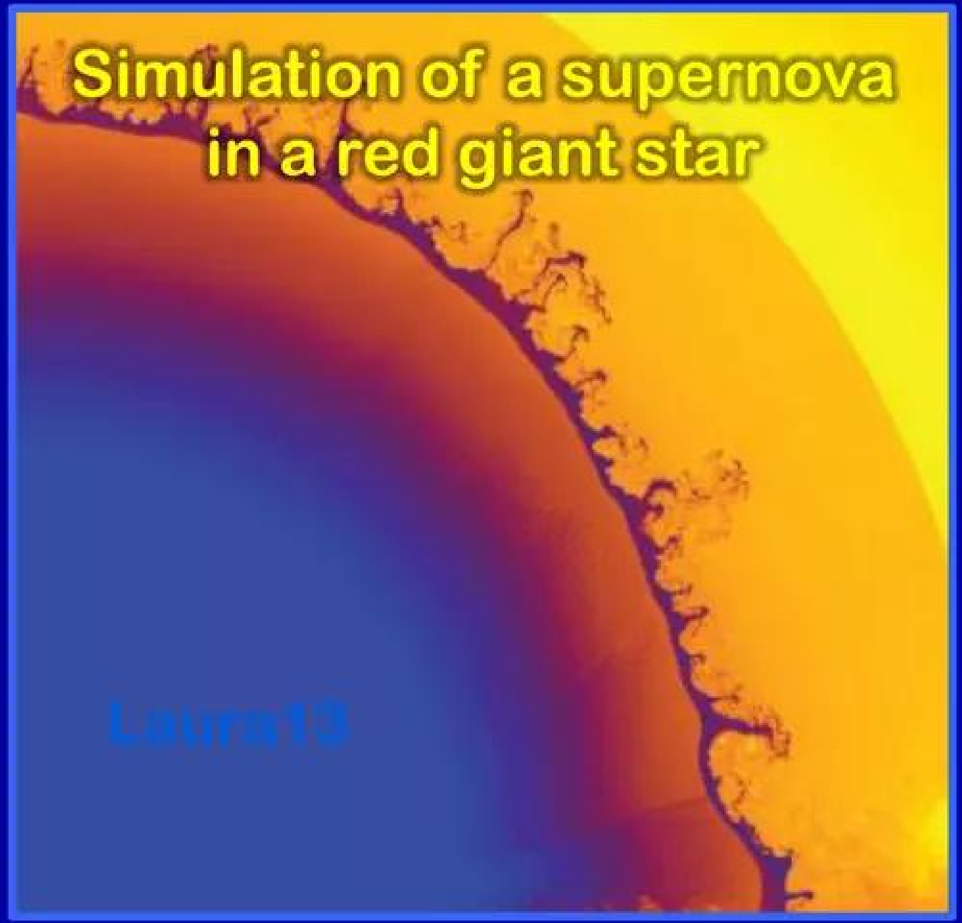


Image credit: TeraScale Supernova Initiative

LLNL's NIF (D+T fusion) facility

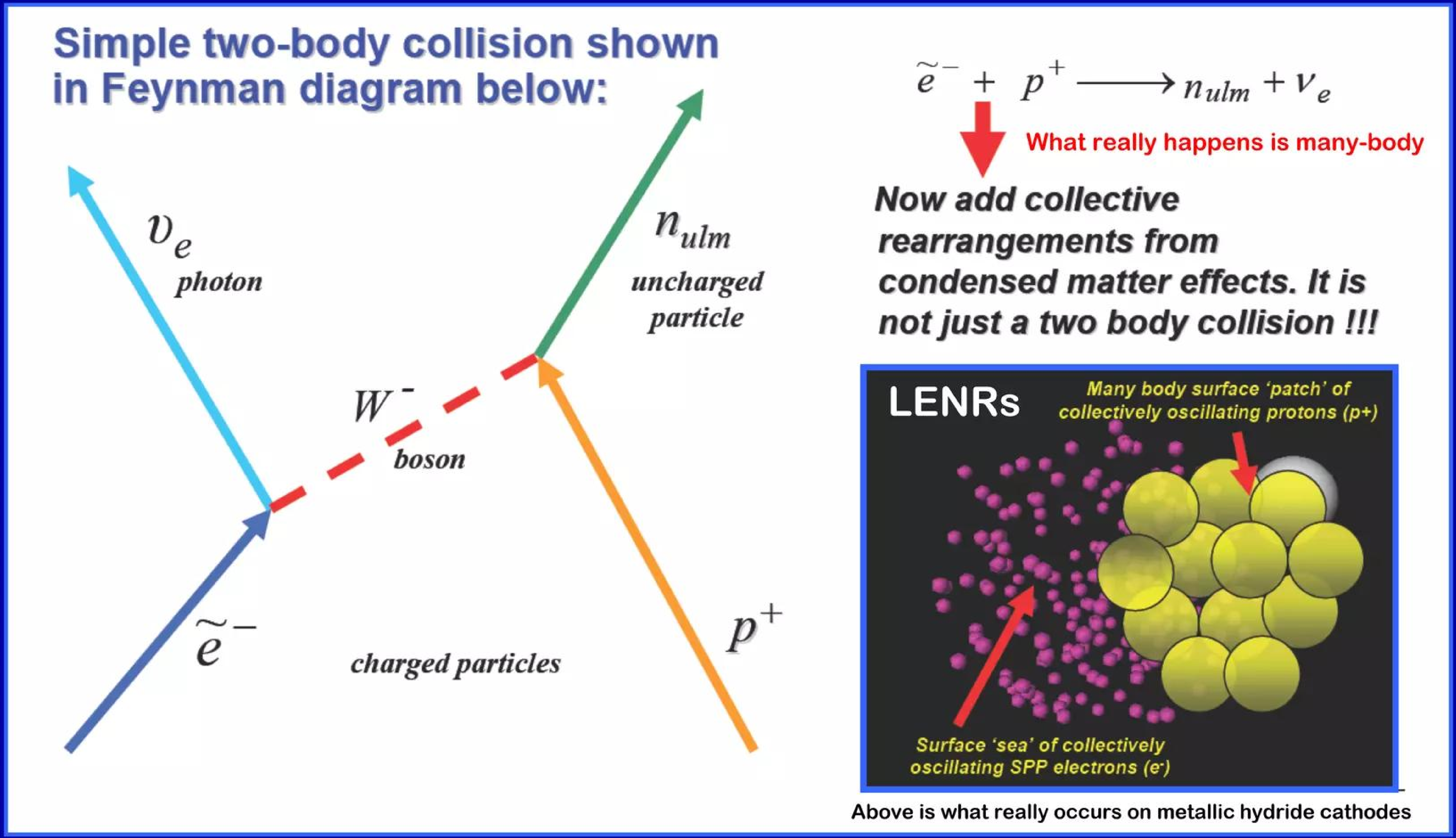


National Ignition Facility: "One series of NIF experiments is studying hydrodynamic instabilities in supernovae. This simulation, created by team member Tomasz Plewa from Florida State University, shows Rayleigh-Taylor instability growth during a supernova in a red supergiant star."

Many-body collective quantum effects crucial to LENRs

While written as two-body $e^- + p^+$ reaction LENR catalysis is many-body

Condensed matter many-body collective effects involve quantum entanglement



Electroweak reaction in Widom-Larsen theory is simple

Protons or deuterons react directly with electrons to make neutrons

W-L explains how *e* + *p* reactions occur at substantial rates in condensed matter

Draw energy from electric fields > 2.5 x10^{11} V/m | **Heavy-mass e^{-*} electrons react directly with protons**

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

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

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

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

Induce nuclear transmutation

Neutrons + atomic nuclei → heavier elements + decay products

LENR catalysis boosts electroweak $e + p$ reaction rate

Collective effects & Q-M entanglement make it a many-body reaction

Energy to drive reaction comes from electric fields not particle kinetic energies

Increased effective electron mass solves the mass deficit problem with $e + p$ reaction rates

- ✓ In coherently oscillating. Q-M entangled patches of surface protons, deuterons, or tritons the Born-Oppenheimer approximation breaks down; this causes local electromagnetic coupling between surface plasmon (SP) electrons and protons, deuterons, or tritons associated/entangled with an LENR many-body active site and enables transient, nuclear-strength, collective local electric fields > 2.5×10^{11} V/m to be created therein. Site conceptually akin to gigantic 'naked' pancake-shaped, micron+ diameter atomic nucleus (*sans* strong force) resting on a substrate surface

- ✓ LENR active site SP electrons locally bathed in nuclear-strength electric fields undergo a phenomenon called "mass renormalization" whereby their masses effectively increase. This effect, upon which the W-L theory of LENR electroweak catalysis relies, was first discovered and published by famous Russian physicists in 1970s (Landau & Lifshitz, "The Classical Theory of Fields", Sects. 17 and 47, Prob. 2, Pergamon Press, Oxford 1975 and Berestetskii, Lifshitz, & Pitaevskii, "Quantum Electrodynamics", Sect. 40, Eq. 40.15, Butterworth Heinmann, Oxford, 1997). Effect is uncontroversial and well-accepted among high-energy particle physicists

- ✓ Since such electrons are not increasing mass via kinetic energy associated with high-velocity translational motion, no bremsstrahlung radiation will be produced

Radiation-free green transmutations in mild conditions

Electrons react directly with protons to make neutrons and neutrinos

Reactions are 'green': no deadly emissions of energetic neutrons and gammas

Non-stellar neutron production in condensed matter under mild conditions:

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 nuclear reactions produce neutrons (n) and neutrinos (ν_e)

Transmutation of elements and star-like nucleosynthesis in labs and Nature:

Neutron capture-driven transmutation in Earthly environs

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

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

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

Can create heavier stable isotopes/elements along rows of Periodic Table

W-L theory posits that LENRs are a multi-step process

Summary of key steps that occur in electroweak catalysis of neutrons

Five-step hard-radiation-free process occurs in 200 - 400 nanoseconds or less

1. Collectively oscillating, quantum mechanically entangled, many-body patches of hydrogen (protons or deuterons) form spontaneously on metallic surfaces

2. Born-Oppenheimer approximation spontaneously breaks down, allows E-M coupling between local surface plasmon electrons and patch protons; enables application of input energy to create nuclear-strength local electric fields > 2.5 x 10^{11} V/m - increases effective masses of sites' surface plasmon electrons

3. Heavy-mass surface plasmon electrons formed in many-body active sites can react directly with electromagnetically interacting protons; process creates neutrons and benign neutrinos via a collective electroweak $e + p$ reaction

4. Neutrons collectively created in such sites have ultra-ultra-low kinetic energies; almost all are captured by nearby atoms - few neutrons escape into environment; locally produced or ambient gammas converted directly into infrared photons by unreacted heavy electrons (US# 7,893,414 B2) - no deadly gamma emissions

5. Transmutation of atoms of locally present elements is induced at active sites

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

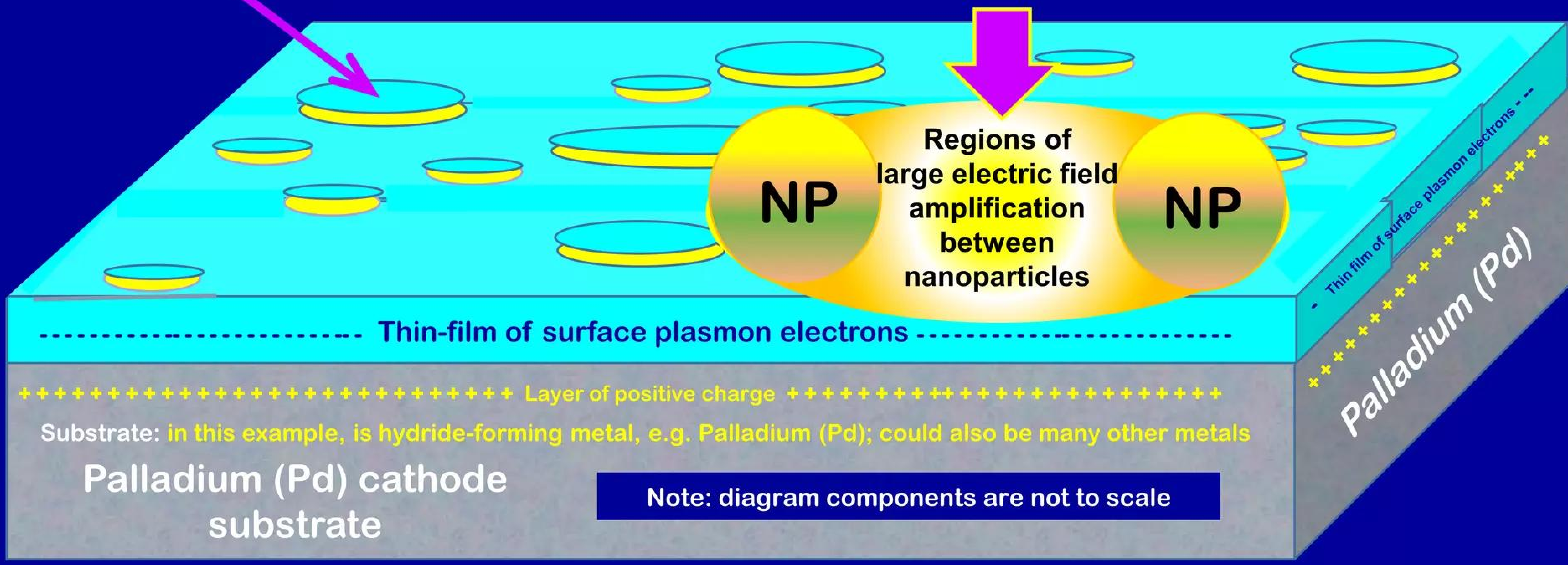
Intense heating in LENR-active sites will form μ-scale craters on certain substrate surfaces

After being produced, neutrons will capture on nearby atoms:

n + (Z, A) → (Z, A+1) [local atoms compete to capture neutrons]

(Z, A+1) → (Z + 1, A+1) + e_{β}^{-} + ν_e [beta$^-$ decay]

Captures often followed by β^- decays of neutron-rich intermediate LENR products

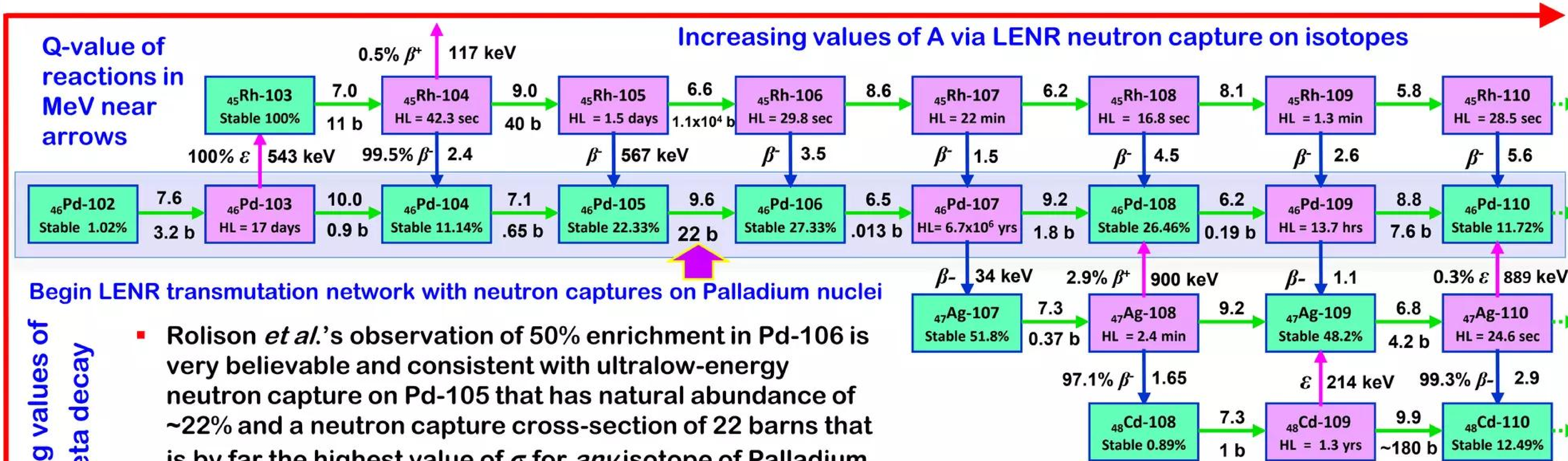


Widom-Larsen posits neutron captures and various decays

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

W-L neutron-catalyzed LENR transmutation network on Palladium is below

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



Increasing values of Z via Beta decay

- 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

'Smoking gun' for neutron capture on Palladium isotopes

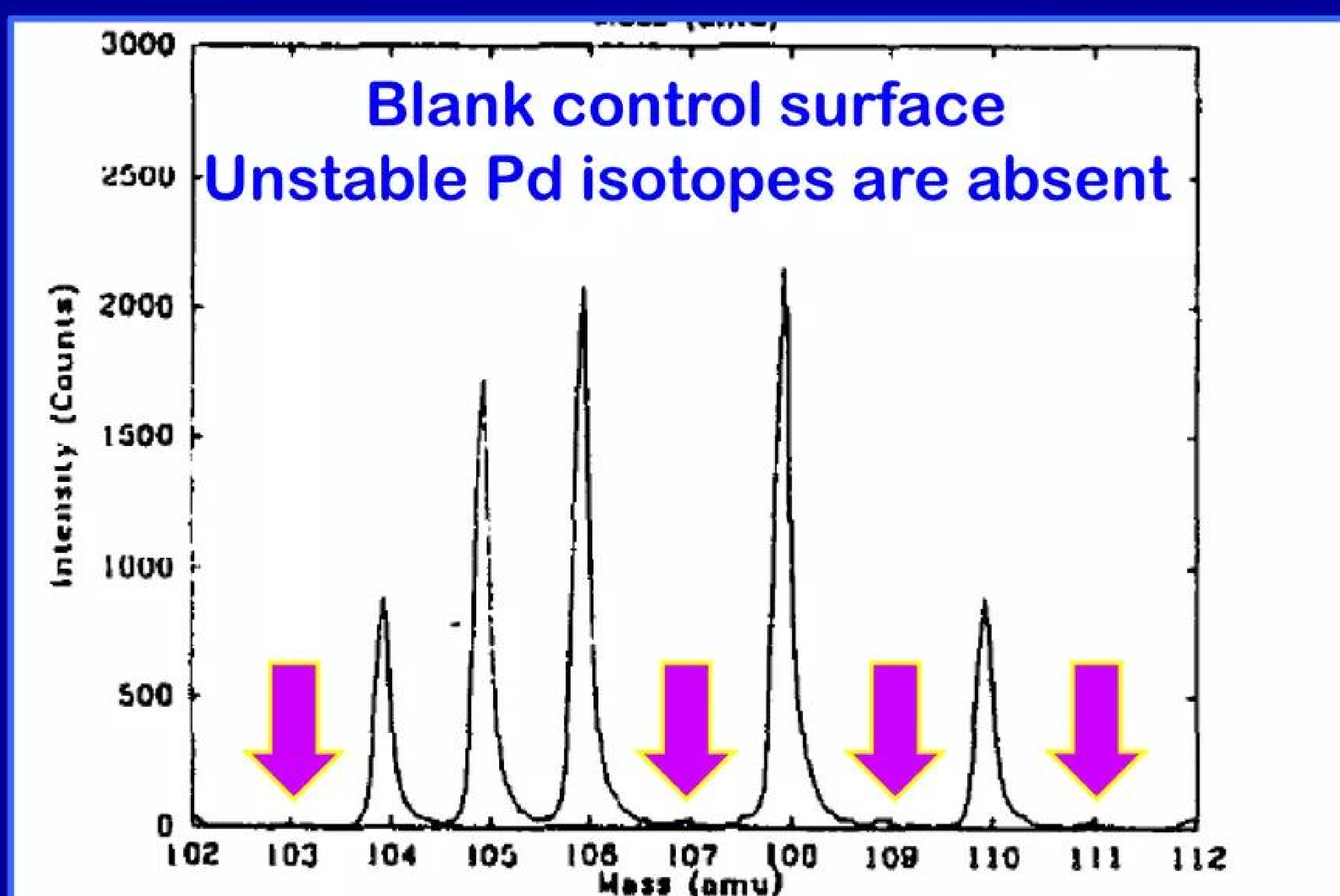
Occurs exactly as predicted by Widom-Larsen theory of LENRs

Rare unstable isotopes of Pd would not be found in natural samples

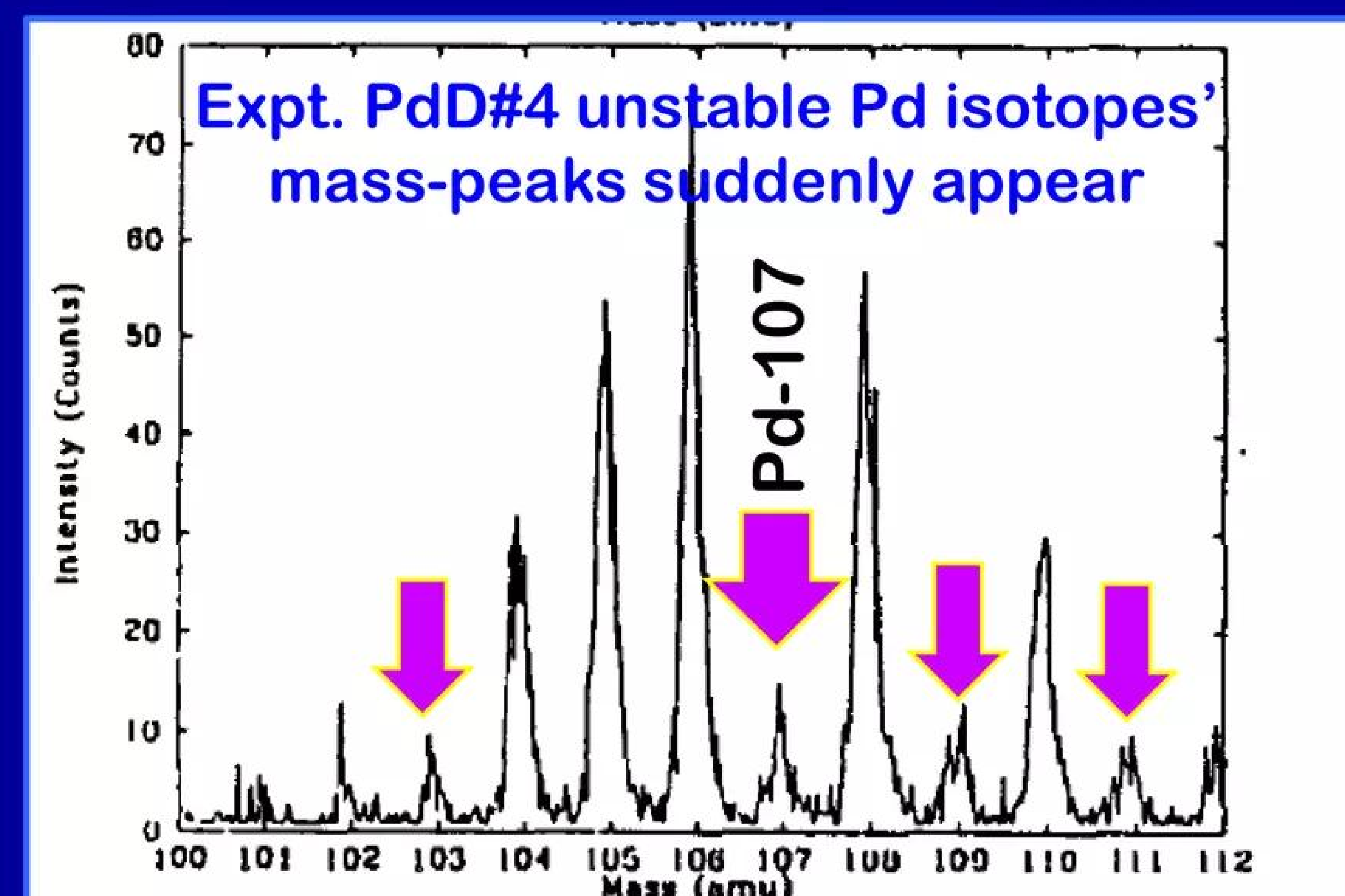
Examine unstable Palladium isotopes Pd-103, Pd-107, Pd-109, and neutron-rich Pd-111 in LENR neutron-catalyzed transmutation network shown on previous slide

Data reported by Rolison *et al*. of NRL at EPRI-NSF Workshop in October 1989

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

Rolison *et al*. conducted further experiments on Pd

Reported additional TOF-SIMS data at ICCF-1 conference in 1990

Previous isotopic shift results reported at EPRI-NSF in 1989 were reaffirmed

Pd LENR network is capable of producing Rhodium (Rh); Silver (Ag), and Cadmium (Cd)

ANOMALIES IN THE SURFACE ANALYSIS OF DEUTERATED PALLADIUM

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See LENR network on previous slide

Two samples electrolyzed in D_2O exhibited greater than 20% enrichments in m/z 106 intensity and diminutions in m/z 105 intensity [2]. This result is provocative because of the implication that ^{105}Pd obtained a neutron to generate ^{106}Pd. The more startling ^{106}Pd enrichment (≈100% over ideal) was observed for the only sample electrolyzed in LiOD; an enrichment of ≈45% was observed for one of the samples electrolyzed in Li_2SO_4. It was shown using the Pd blanks and the sample used to electrolyze H_2O that the conditions of the TOF-SIMS measurements, including *in-situ* plasma cleaning of the samples, were not responsible for the enrichment/diminution phenomena [2].

segregation in a foil on the order of 10^2-μm thick. As both Ag and Rh appear at the surface of Pd charged in either D_2O or H_2O, a mechanism based on surface segregation and forced diffusion as the Pd lattice is filled with $H^\cdot$ or $D^\cdot$ atoms seems more probable than one relying on known neutron activation reactions of Pd isotopes, some of which yield stable Ag and Rh isotopes [10]. Intriguing though this latter prospect may be, experiments with 99.999% Pd would be required before a physical transport mechanism could start to be discounted.

Screen capture snippets of text from pages #272 and #275 in ICCF-1 conference *Proceedings* document

Rolison *et al*. used TOF-SIMS & XPS in 1990 experiments

Noted presence of Rh & Ag anomalies on Pd surfaces post-experiment

Invoked a forced-diffusion migration of Rh/Ag from bulk Pd lattice to explain this

Forced diffusion dubious because Platinum isotope shifts show clear presence of neutrons

Elemental analysis of the Pd surface before and after electrolysis was performed with a Surface Sciences Instruments Model SSX-100-03 X-ray photoelectron spectrometer with a small-spot capability and equipped with an Al anode. Foils analyzed immediately after electrolysis

To avoid ascribing presence of Rh or Ag on cathode surfaces to neutron-captures and decays, Rolison *et al.* proposed *ad hoc* forced-diffusion transport process that first migrated bulk Pd traces of Rh (50 ppm) / Ag (100 ppm) and then greatly concentrated them onto the Pd surfaces

Since electrical current provides external input energy required to produce neutrons via *e* + *p* electroweak reaction, observation that Rh detected via XPS increased in proportion to total accumulated charge in Coulombs would also be very consistent with the Widom-Larsen theory of LENRS

Although Rh and Ag are present in our Pd stock at a concentration below the limit of detection by XPS, after electrolysis of either D_2O or H_2O, Rh and Ag can be detected at the surface of the Pd by signal averaging tens of high resolution scans. The concentrations of Rh and Ag maximize at 3 and 1 atom%, respectively, relative to the Pd signal [3].

The concentration of the Rh increased as a function of total accumulated charge, but plateaued at ≈3 atom% [3].

Annotated screen capture snippets of text from page #273 in ICCF-1 conference *Proceedings* document

1990 data further bolsters case for low-energy neutrons

Noted Pd isotopic shifts can potentially be caused by neutron capture

"Enrichment at m/z 106 cannot be attributed to … plausible chemical interferents"

Comments: Rolison *et al.* explicitly recognized possibility that their anomalous Pd isotopic shifts and odd "surface segregation" of Rh/Ag atoms could be explained by a combination of neutron captures on Pd isotopes and nuclear decays of unstable products to Rhodium and Silver. However, given a perplexing absence of MeV-energy prompt capture gammas and no readily detectible, significant fluxes of neutrons that would be expected under then-prevailing key conceptual paradigms about nuclear processes, they were still reluctant to directly challenge the consensus status quo

CONCLUSIONS

Our surface analytical characterizations of Pd-H_2O and Pd-D_2O systems have produced a number of unusual results involving:

(i) a relative enrichment at m/z 106 that cannot be attributed to heretofore-identified plausible chemical interferents;

(ii) segregation of metallic impurities (present in the bulk Pd at 10^2-ppm levels) to the surface of the more resistive, but still conductive PdD_x or PdH_x at atom-% levels;

Screen capture snippet of text from page #280 in ICCF-1 conference *Proceedings* document

LENR network produces excess heat and He-4 in P&F cells

Predicted by the Widom-Larsen theory and published in *EPJC* (2006)

Radiation-free network explains Lithium isotope shifts reported by LLNL

Widom & Larsen's 2006 *European Physical Journal C* paper shows the following Lithium-target LENR network cycle:

Lithium-6 + 2 ULM neutrons → 2 Helium-4 + beta particle + 2 neutrinos + Q-value = 26.9 MeV

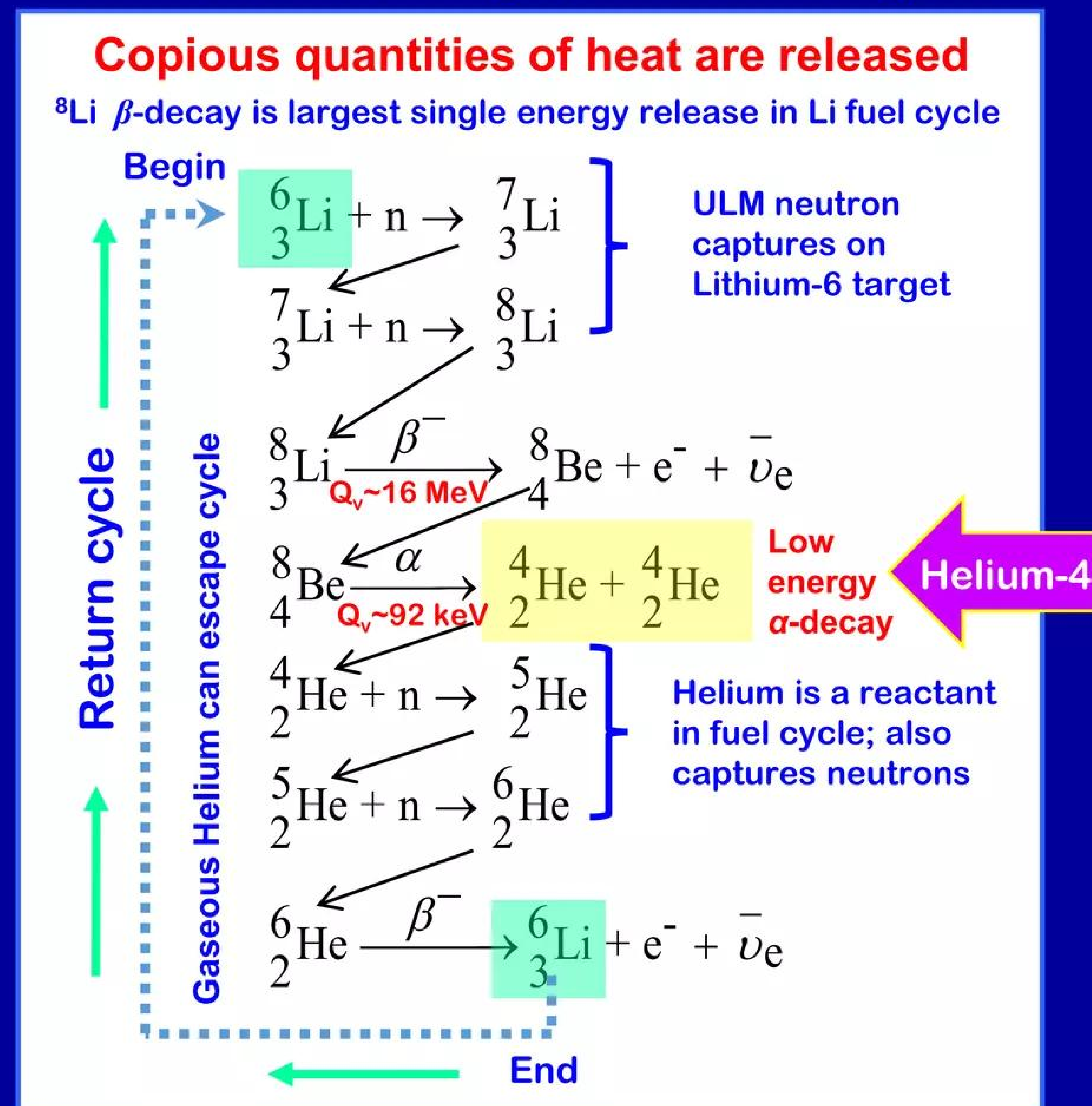
This particular cyclical LENR network can release about the same amount of energy as the D-T fusion reaction without creating any MeV-energy energetic neutrons, hard gamma radiation, or radioactive isotopes. Although a portion of the 26.9 MeV in excess nuclear binding energy released is lost (haircut)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

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

See paper: "Ultra low momentum neutron catalyzed nuclear reactions on metallic hydride surfaces" A. Widom and L. Larsen in the *European Physical Journal C - Particles and Fields* 46 pp. 107-111 (2006)

Neutron-catalyzed LENR Lithium fuel network in Eqs. 30 - 32

LENR neutron-catalyzed Lithium fuel cycle



Thomas Kuhn outlines his idea of a good scientific theory

Published seminal 1962 book "The Structure of Scientific Revolutions"

Widom-Larsen many-body collective theory of LENRs fulfills Kuhn's five criteria

"What, I ask to begin with, are the characteristics of a good scientific theory?"

"First, a theory should be accurate: within its domain, that is, consequences deducible from a theory should be in demonstrated agreement with the results of existing experiments and observations. Second, a theory should be consistent, not only internally or with itself, but also with other currently accepted theories applicable to related aspects of nature. Third, it should have broad scope: a theory's consequences should extend far beyond the particular observations, laws, or subtheories it was originally designed to explain. Fourth, and closely related, it should be simple, bringing order to phenomena that in its absence would be individually isolated and, as a set, confused. Fifth --- a somewhat less standard item, but one of special importance to actual scientific decisions --- a theory should be fruitful of new research findings: it should, that is, disclose new phenomena or previously unnoted relationships among those already known."

"These five characteristics --- accuracy, consistency, scope, simplicity, and fruitfulness … provide the [standard criteria] … for theory choice."

Thomas Kuhn, "Objectivity, Value Judgment, and Theory Choice" pp. 321 - 322 in Chapter 13 of "The Essential Tension - Selected Studies in Scientific Tradition and Change", The University of Chicago Press (1977)

Brian Arthur explains why aging paradigms can persist

Previous conceptual paradigms die hard because change is resisted

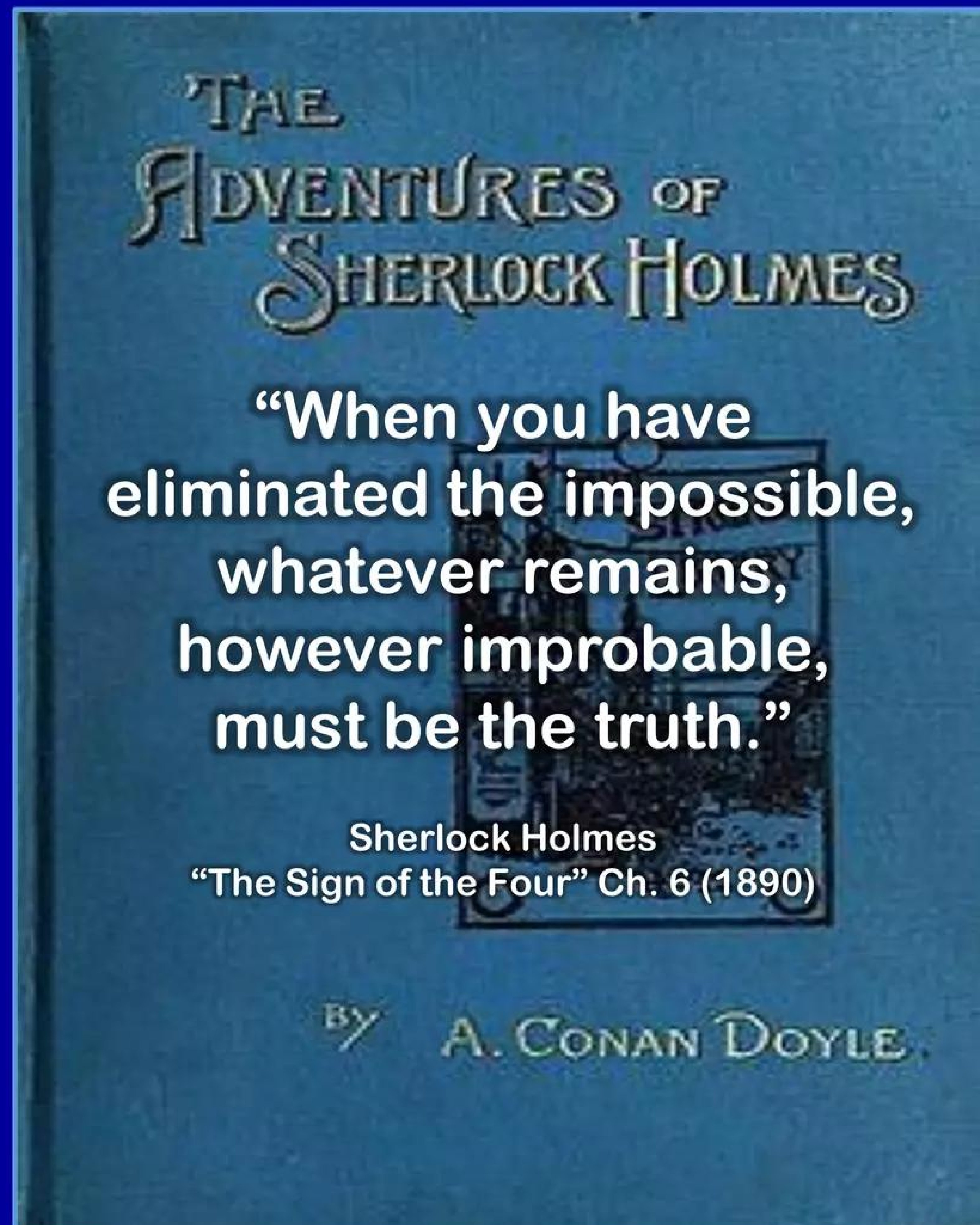
pp. 138 "… eventually there comes a time when neither component replacement nor structural deepening [of the older, dominant paradigm] add much to performance. If further advancement is sought, a [new] novel principle is needed."

pp. 139 "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 lack of imagination. But because it creates a cognitive dissonance, an emotional mismatch, between the potential of the new and the security of the old."

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

Lattice Energy LLC

Commercializing a next-generation source of green nuclear energy



Publisher: George Newnes (1892)