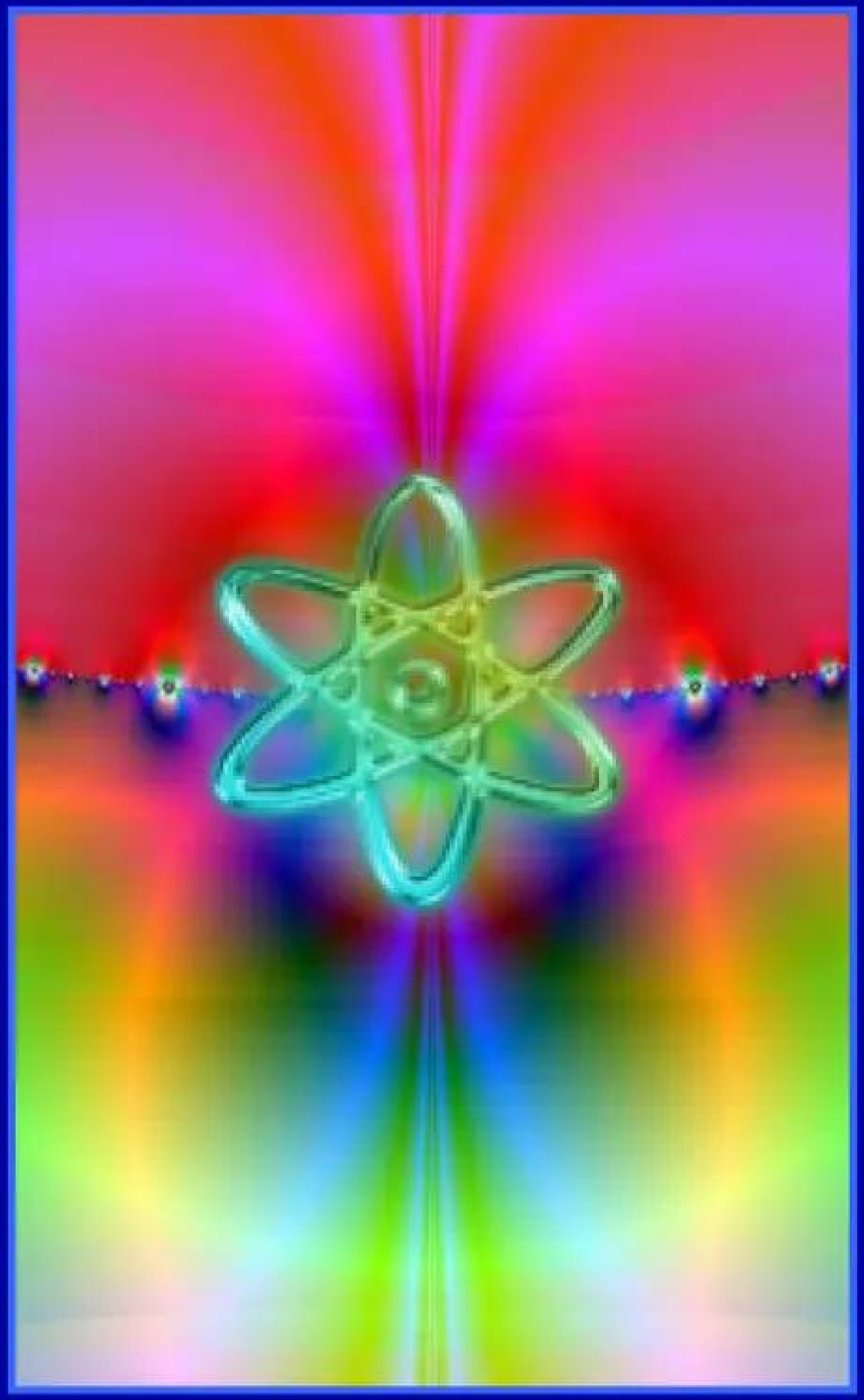
Powering the world to a green future

Truly green nuclear energy exists

No deadly gammas … No energetic neutrons … No radioactive waste

Can be described as clean low energy neutron reactions or LENRs

Based on collective many-body electroweak processes instead of few-body fission or fusion



Overview

for everybody

Lewis Larsen

President and CEO
Lattice Energy LLC

April 11, 2013 (v.4 updated though June 28, 2013)

“I have learned to use the word ‘impossible’
with the greatest caution.”

Wernher von Braun

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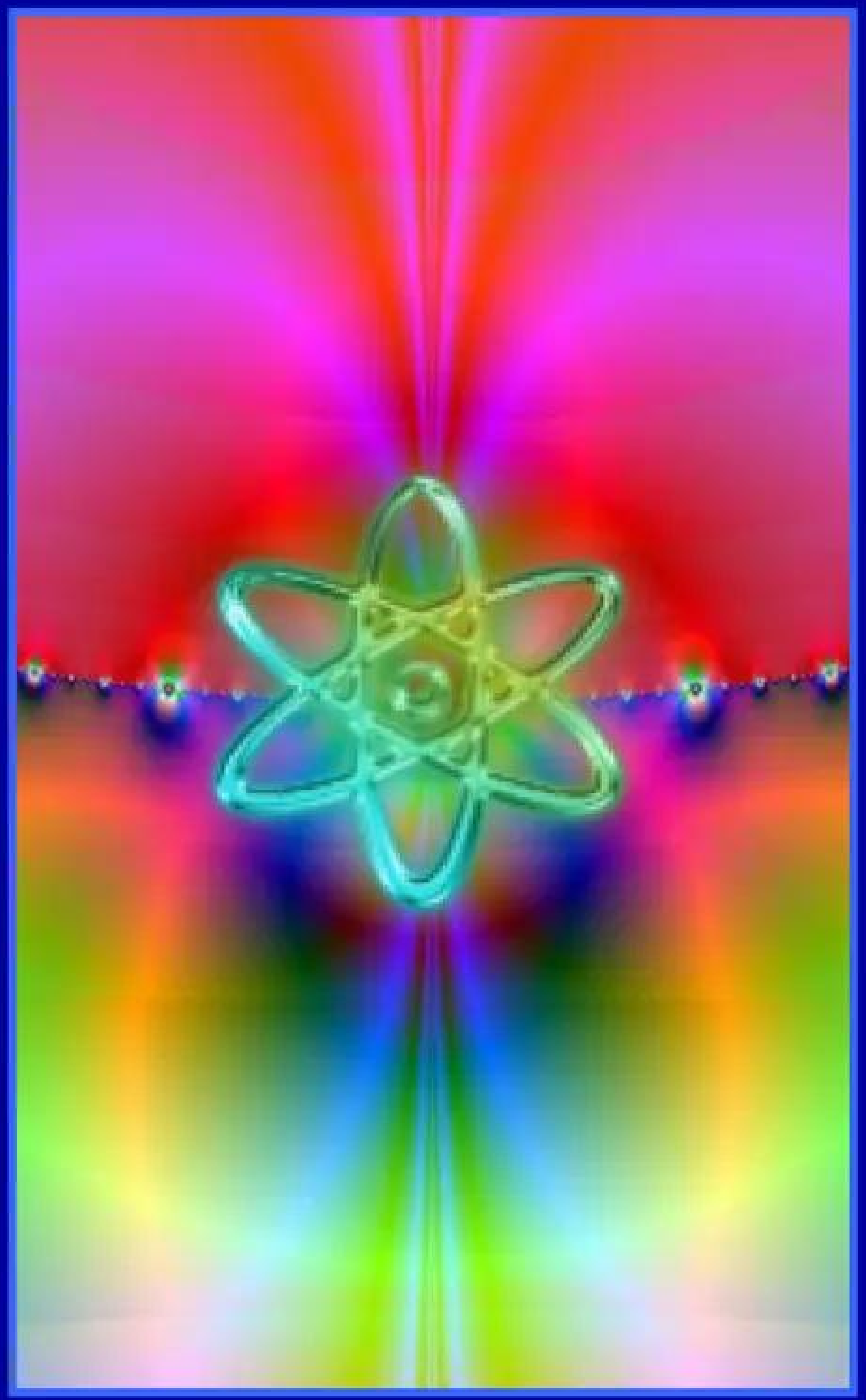
http://www.slideshare.net/lewisglarsen



Powering the world to a green future

Truly green nuclear energy exists

“I have learned to use the word ‘impossible’ with the greatest caution.”

Wernher von Braun

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

Thomas Friedman
***New York Times*, April 28, 2006**

Powering the world to a green future

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

This lead to the idea of mimicking stellar fusion processes to generate power

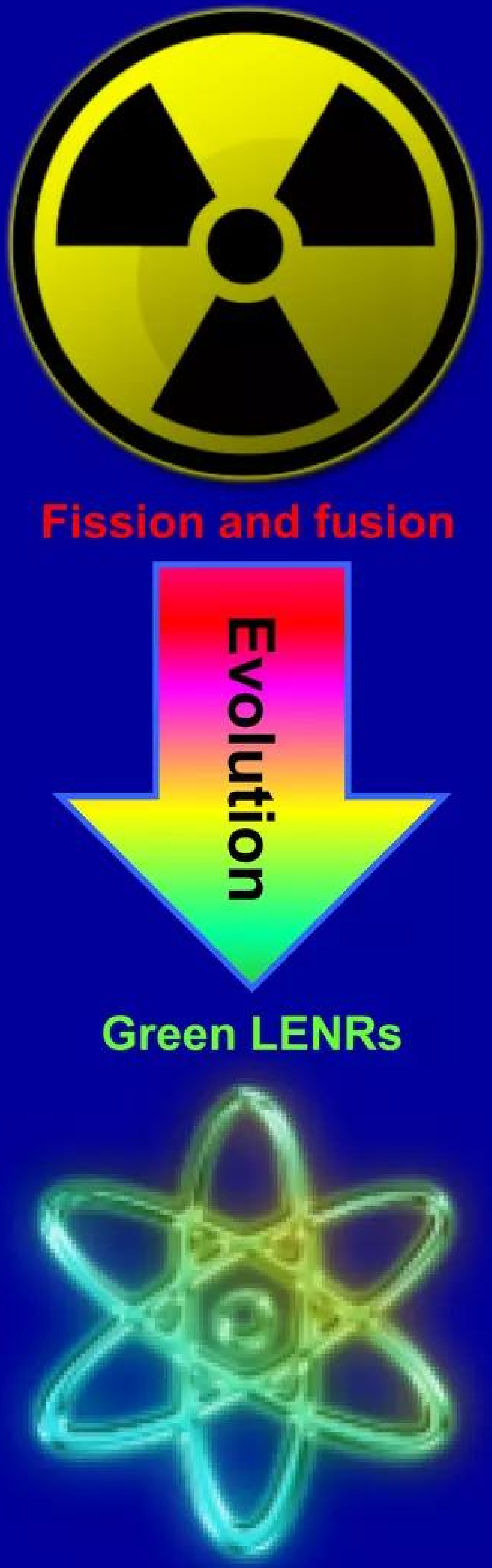
- ✓ Beginning with Hans Bethe’s landmark paper published back in in 1939, the ‘Holy grail’ and longstanding dream of nuclear science has been to commercialize the same ‘clean’ fusion reactions that power stars and our Sun
- ✓ Less technically difficult fission technology was first utilized and deployed in commercial nuclear reactors; it has been fraught with safety, cost, and serious proliferation issues that are well-known *a la* Dr. Evgeny Velikhov’s “vital risks”
- ✓ Both fission and fusion rely primarily on the strong interaction and are triggered by few-body energetic ‘taekwondo’ (that we will explain herein); accordingly, both processes release deadly hard radiation and produce long-lived isotopes
- ✓ Up until the advent of the collective many-body Widom-Larsen theory in 2005, the weak interaction was thought to be useless for large-scale power generation
- ✓ Thanks to Widom-Larsen, we now know that radiation-free, truly ‘green’ LENRs based on the weak interaction are enabled by physics ‘aikido’ in condensed matter and can occur at very substantial rates under exactly the right conditions
- ✓ We are thus facing a paradigm shift in ongoing evolution of nuclear technology

Powering the world to a green future

Truly green nuclear energy exists

LENRs only recently appreciated by science because deadly radiation is absent

- ✓ **Nuclear power technologies: gradually evolving toward safer, ‘greener’ types of processes that release nuclear binding energy (>1 million times chemical processes such as burning fossil fuels) without injecting CO_2 into biosphere**
- ✓ **Fission of unstable Uranium and Plutonium: first commercial power generation technology starting in 1950s; hasn’t achieved extremely broad deployment that was previously hoped-for because of public’s issues with perceived safety, unsolved radioactive waste disposal problems, and serious weapons proliferation concerns regarding rogue states and terrorist non-state actors**
- ✓ **Fusion (mostly Deuterium-Tritium): power generation researched since 1950s; still without a working commercial fusion reactor after investing many billions of $ and vast numbers of man-hours by thousands of scientists; mainly ITER and NIF (US) to show for it - will fusion power require yet another 20+ years?**
- ✓ **Evgeny Velikhov (ITER report, Dec. 2012): says “vital risks” still accompany present-era nuclear technologies; suggests fission-fusion “hybrids” might provide alternative solution for widely deployed power generation systems**
- ✓ **Enter LENRs: inexplicable anomalous experimental effects seen for almost 100 years; initially not ascribed to nuclear processes because strong radiation signatures are absent; finally theoretically understood by Widom & Larsen in past 8 years; now have an opportunity to develop truly ‘green’ nuclear power**


Fission and fusion

Green LENRs

Powering the world to a green future

Paradigm shift: ‘green’ radiation-free nuclear processes

Absence of ‘hard’ radiation: LENRs were hidden in plain sight for 100 years

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

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

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

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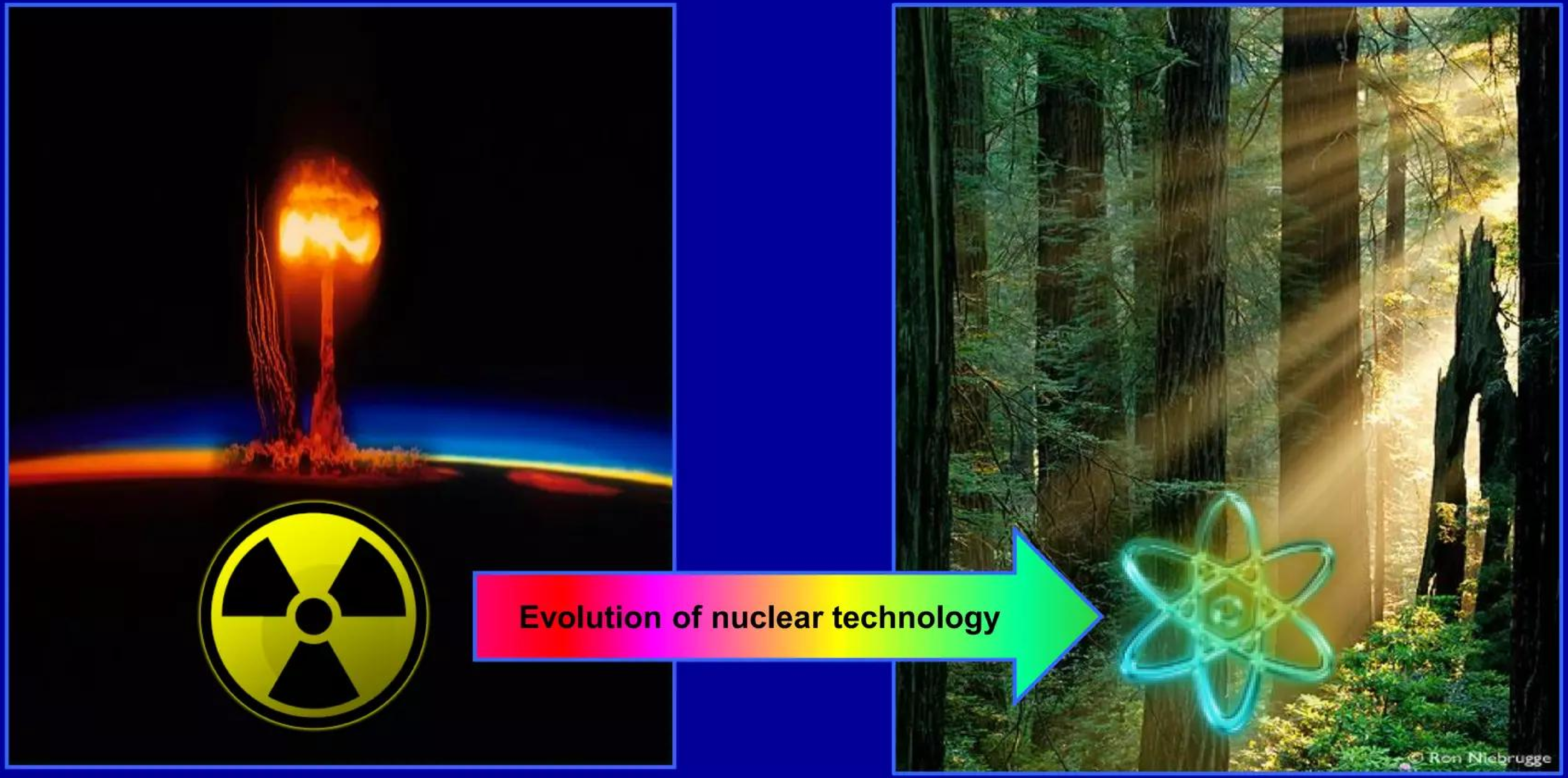
LENRs don't need radiation shielding or confinement

'Green' nuclear process should be able to address all Velikhov's "vital risks"

From the "vital risks" of today | **To a 'green' nuclear tomorrow**



Evolution of nuclear technology

Fission and fusion

Clean radiation-free LENRs

Powering the world to a green future

Alternative dense energy sources

LENRs provide opportunity to develop vastly ‘greener’ new energy source

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

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

Scale of energy release: eVs (chemical regime)

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

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

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

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

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

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

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

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

Fusion of light nuclei: (involves ‘mashing’ light nuclei together to release stored nuclear binding energy):

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

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

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

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

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

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

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

Contents - I

Overview of LENR technology and related science

Commercialization, market applications, and business-related issues are covered in the next section; non-scientists may wish to read through Slide #17 and then skip forward to Slide #83

Powering the world to a green future

Contents - II

Commercialization, market applications, and business-related issues

Relevant articles about the future of nuclear technology

"Future Development of Nuclear Power and Role of Fusion Neutron Source - Green Nuclear Power"
Dr. Evgeny Velikhov, President, Kurchatov Institute, Moscow, Russia
ITER Report, December 2012 (34 MS-PowerPoint slides)
http://www.iter.org/doc/www/content/com/Lists/Stories/Attachments/1413/Hybrids.pdf

"NNSA's Path Forward to Achieving Ignition in the Inertial Confinement Fusion Program"
U.S. Dept. of Energy, Report to Congress, December 2012 (37-pages in MS-Word)
http://fire.pppl.gov/NIF_Path_Forward_Rpt_120712.pdf

"Commercializing Low Energy Nuclear Reactions (LENRs):
Cutting Energy's Gordian Knot - A Grand Challenge for Science and Energy"
Lattice White Paper, Lewis Larsen, April 12, 2010 (16-page extract from 62-page report)
http://www.slideshare.net/lewisglarsen/cfakepathlattice-energy-llc-white-paper-excerptapril-12-2010

Peer-reviewed papers about the Widom-Larsen theory

"A primer for electroweak induced low-energy nuclear reactions"
Y. N. Srivastava, A. Widom, and L. Larsen
***Pramana – Journal of Physics* 75 (4) pp. 617 - 637 (2010)**
http://www.ias.ac.in/pramana/v75/p617/fulltext.pdf

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

I-SiS articles on LENRs were written for a broad audience

"Low energy nuclear reactions for green energy - how weak interactions can provide sustainable nuclear energy and revolutionize the energy industry," Institute of Science in Society, London, UK, Larsen (Nov. 13, 2008)
http://www.i-sis.org.uk/LENRGE.php

"Widom-Larsen theory explains low energy nuclear reactions & why they are safe and green - all down to collective effects and weak interactions," Institute of Science in Society, London, UK, Larsen (Dec. 4, 2008)
http://www.i-sis.org.uk/Widom-Larsen.php

"Portable and distributed power generation from LENRs - power output of LENR-based systems could be scaled up to address many different commercial applications," Institute of Science in Society, London, UK, Larsen (Dec. 10, 2008)
http://www.i-sis.org.uk/PortableDistributedPowerFromLENRs.php

"LENRs for nuclear waste disposal - how weak interactions can transform radioactive isotopes into more benign elements," Institute of Science in Society, London, UK, Larsen (Dec. 11, 2008)
http://www.i-sis.org.uk/LENR_Nuclear_Waste_Disposal.php

"Safe, less costly nuclear reactor decommissioning and more - how weak interaction LENRs can take us out of the nuclear safety and economic black hole," Institute of Science in Society, London, UK, Larsen (Jan. 26, 2009)
http://www.i-sis.org.uk/safeNuclearDecommissioning.php

"LENRs replacing coal for distributed democratized power - low energy nuclear reactions have the potential to provide distributed power generation with zero carbon emission and cheaper than coal," Institute of Science in Society, London, UK, Larsen (Jan. 27, 2009)
http://www.i-sis.org.uk/LENRsReplacingCoal.php

Powering the world to a green future

LENRs potentially much better than fission or fusion

Stars, fission reactors, tokamaks, and thermonuclear explosions - not required

LENRs do not have Velikhov's "vital risks" yet release comparable amounts of energy

Less Energy Per Reaction

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

Evolution of nuclear technology

Powering the world to a green future

LENRs potentially much better than fission or fusion

Stars, fission reactors, tokamaks, and thermonuclear explosions - not required

Chart ranks competing nuclear energy technologies by 'greenness'

"Greener"

Reactants/Fuel	Reaction Type	Main End Products of Reactions	
Very Heavy Uranium or Plutonium metal atoms + neutrons (chain reaction)	Conventional Fission in Nuclear Power Plants; Strong Interaction	Unstable long-lived radioactive isotopes, hard gamma/ X-ray radiation, energetic neutrons, heat	Taekwondo
Starts With Lightest Atoms Hydrogen + Hydrogen	Fusion in Stars; Strong Interaction	Stable Helium-3/4 isotopes, Mainly fluxes of energetic neutrons, heat	
Starts With Slightly Heavier Isotopes of Hydrogen Deuterium + Tritium	Fusion in Proposed Commercial Reactors; Strong Interaction	Stable Helium-3/4 isotopes, Mainly fluxes of energetic neutrons, heat	
Lighter to Medium-Heavy Atoms + H or D + Electrons + ULMN Neutrons	Heavy and Light Water LENRs; Mainly Weak Interaction	Primarily stable isotopes, no hard radiation, beta and alpha particles, no externally released neutrons, heat	Aikido

Powering the world to a green future

LENRs potentially much better than fission or fusion

Should society start hedging its bets on fusion as a future power source?

- ✓ LENRs can address all Evgeny Velikhov's key "vital risks" noted in ITER document
- ✓ Virtually everyone agrees that development of lower-risk, ecologically 'clean', low cost sources of energy is crucial to future world economic growth and overall quality of life, especially for people now living in rural areas without any electricity
- ✓ Over the past 50 years, enormous financial investments have been made in D-T fusion technology, yet today there are still no operating commercial power plants
- ✓ In last 20 years, tens of billions of dollars, euros, rubles, yuan, yen, and rupees were spent on fusion R&D; by contrast, less than ~US$200 million has gone into LENRs during that time; vast majority of that money came from the private sector
- ✓ Maybe it's time for society to slow down chasing the fusion rainbow and start making greater parallel investments in LENRs in addition to fusion and fission
- ✓ By pursuing multiple synergistic paths toward the same common goal we could, as they say in America, all "hedge our bets" on the development of new, non-polluting, inexpensive energy sources that can ultimately supplant fossil fuels

Powering the world to a green future

Where is nuclear power today and how did we get there?

Selective history of key events and ideas in development of nuclear technology

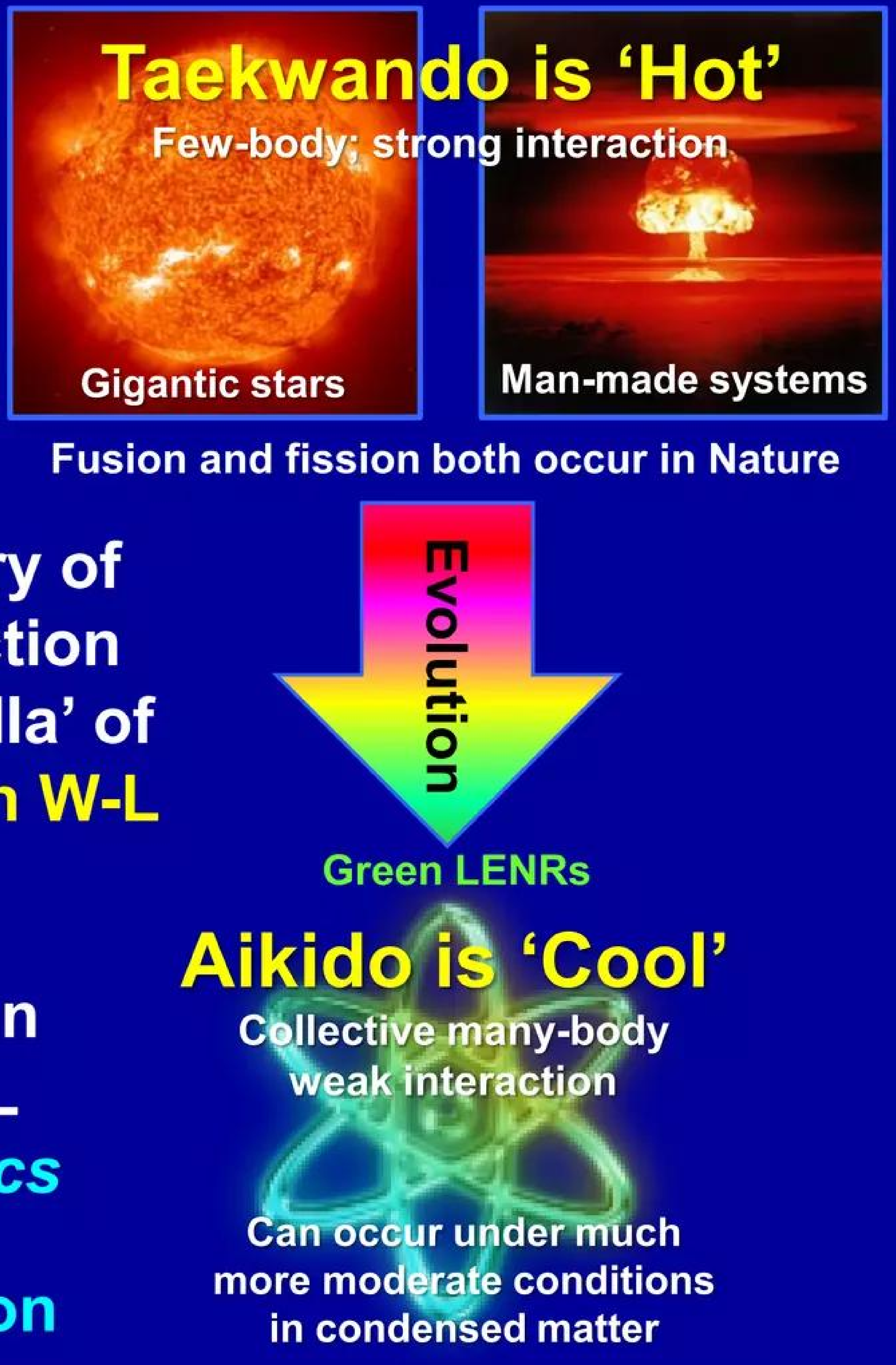
- ✓ Start with Henri Becquerel's discovery of radioactivity in France back in 1896

- ✓ Then touch-upon what we think are key ideas and developments from 1896 up until 2012

- ✓ 2005: Widom & Larsen (W-L) released Cornell arXiv preprint provides first truly rigorous theory of LENRs with key features based on weak interaction and many-body collective effects under 'umbrella' of Standard Model; NO "new physics" anywhere in W-L

- ✓ 2006: 'core' of our theory published in peer-reviewed *European Physical Journal C*; and then in 2010: paper summarizing entire sweep of W-L theory published in *Pramana - Journal of Physics*

- ✓ Today: LENRs finally ready for commercialization



Powering the world to a green future

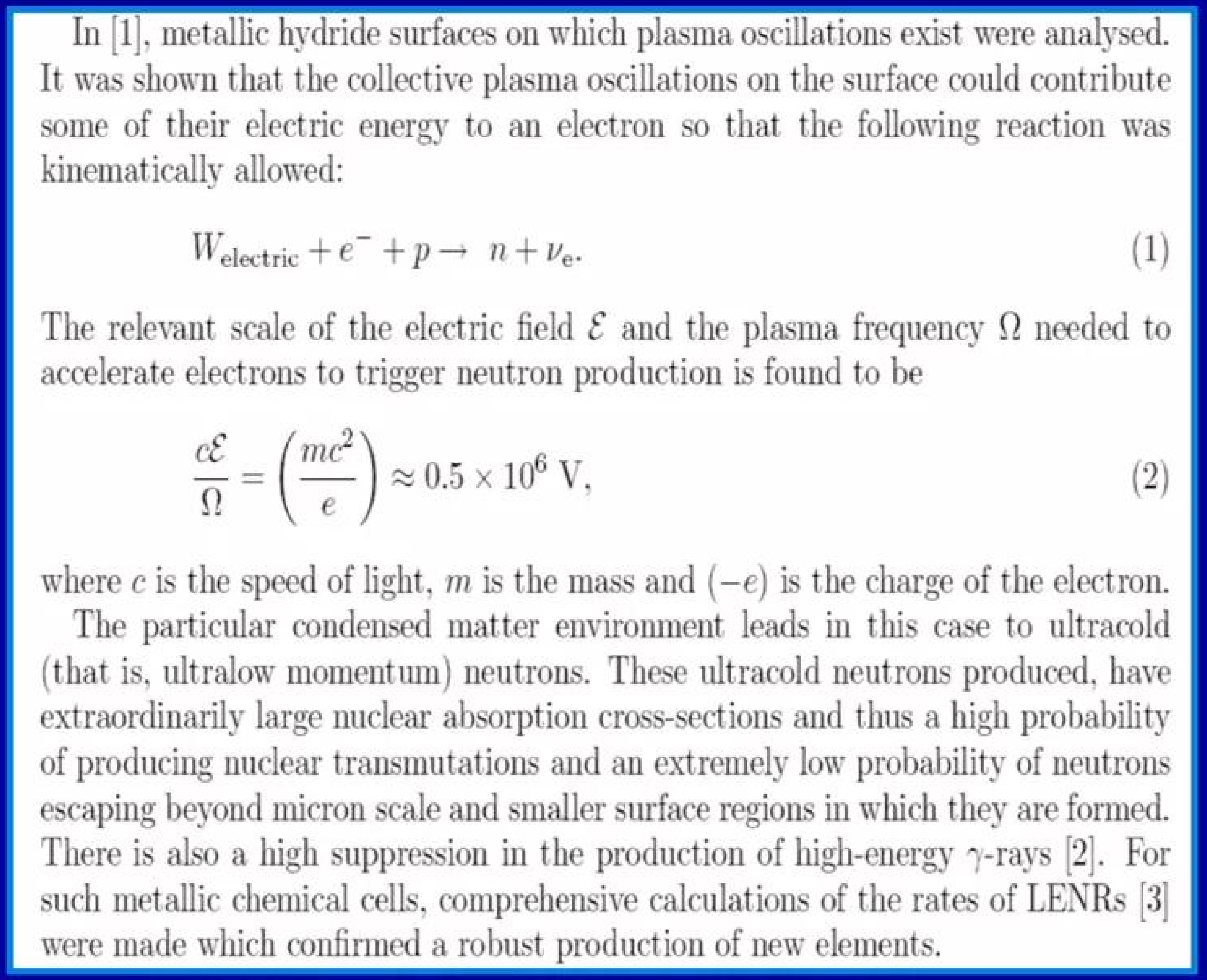
Where is nuclear power today and how did we get there?

Enough is now known about LENRs to begin commercialization

In our *Pramana* W-L theory review paper (2010) we concluded by saying that:

"The analysis presented in this paper leads us to conclude that realistic possibilities exist for designing LENR devices capable of producing 'green energy', that is, production of excess heat at low cost without lethal nuclear waste, dangerous γ-rays or unwanted neutrons. The necessary tools and the essential theoretical know-how to manufacture such devices appear to be well within the reach of the technology available now. Vigorous efforts must now be made to develop such devices whose functionality requires all three interactions of the Standard Model acting in concert."

W-L theory: many-body collective electroweak production of neutrons in condensed matter



In [1], metallic hydride surfaces on which plasma oscillations exist were analysed. It was shown that the collective plasma oscillations on the surface could contribute some of their electric energy to an electron so that the following reaction was kinematically allowed:

$$W_{\text{electric}} + e^- + p \rightarrow \; n + \nu_e. \qquad (1)$$

The relevant scale of the electric field $\mathcal{E}$ and the plasma frequency Ω needed to accelerate electrons to trigger neutron production is found to be

$$\frac{c\mathcal{E}}{\Omega} = \left(\frac{mc^2}{e}\right) \approx 0.5 \times 10^6 \text{ V}, \qquad (2)$$

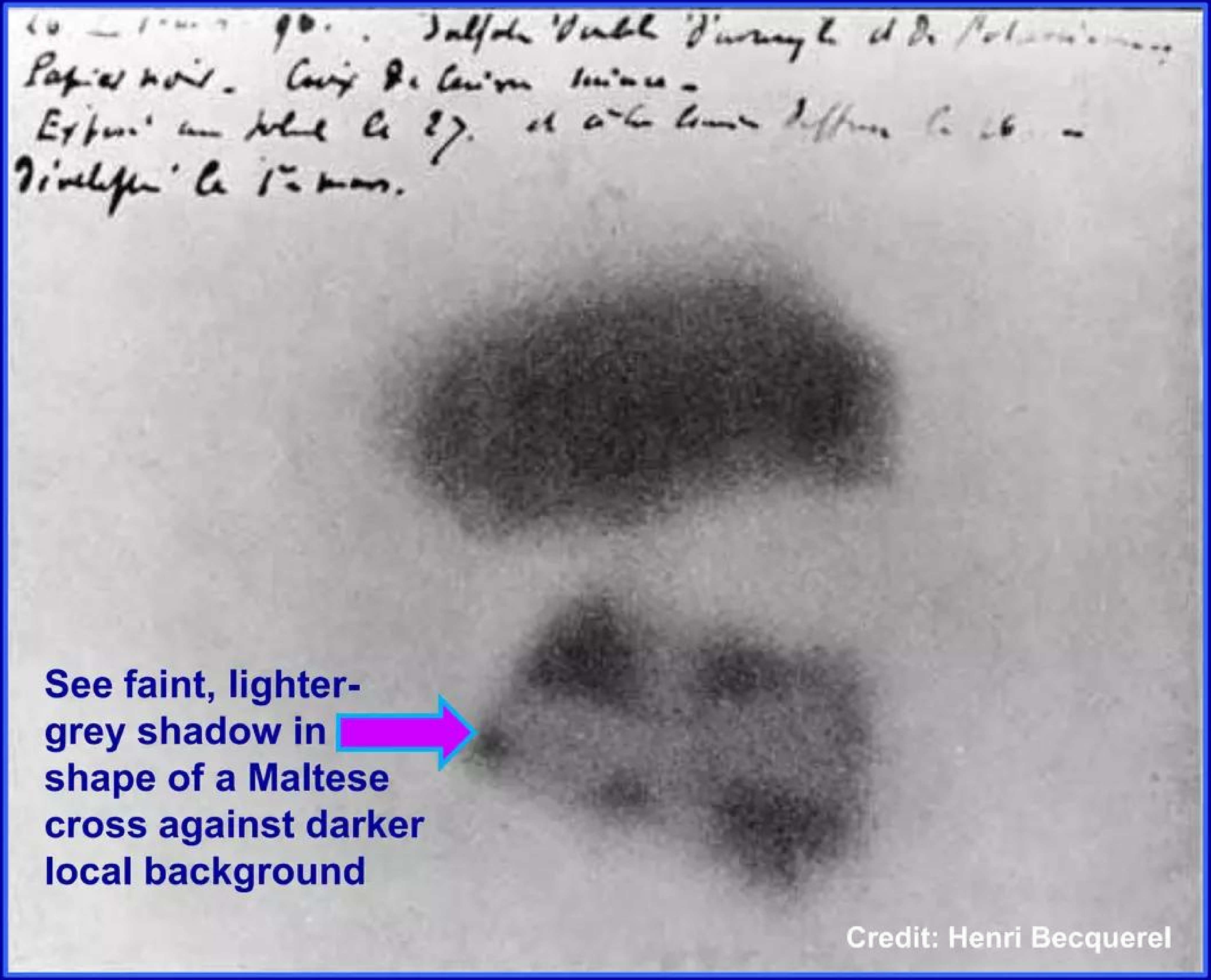
where c is the speed of light, m is the mass and $(-e)$ is the charge of the electron.
The particular condensed matter environment leads in this case to ultracold (that is, ultralow momentum) neutrons. These ultracold neutrons produced, have extraordinarily large nuclear absorption cross-sections and thus a high probability of producing nuclear transmutations and an extremely low probability of neutrons escaping beyond micron scale and smaller surface regions in which they are formed. There is also a high suppression in the production of high-energy γ-rays [2]. For such metallic chemical cells, comprehensive calculations of the rates of LENRs [3] were made which confirmed a robust production of new elements.

Srivastava, Widom, and Larsen: on pp. 3 in *Pramana* paper (2010)

Where is nuclear power today and how did we get there?

Radioactivity was first discovered by Becquerel in France - 1896

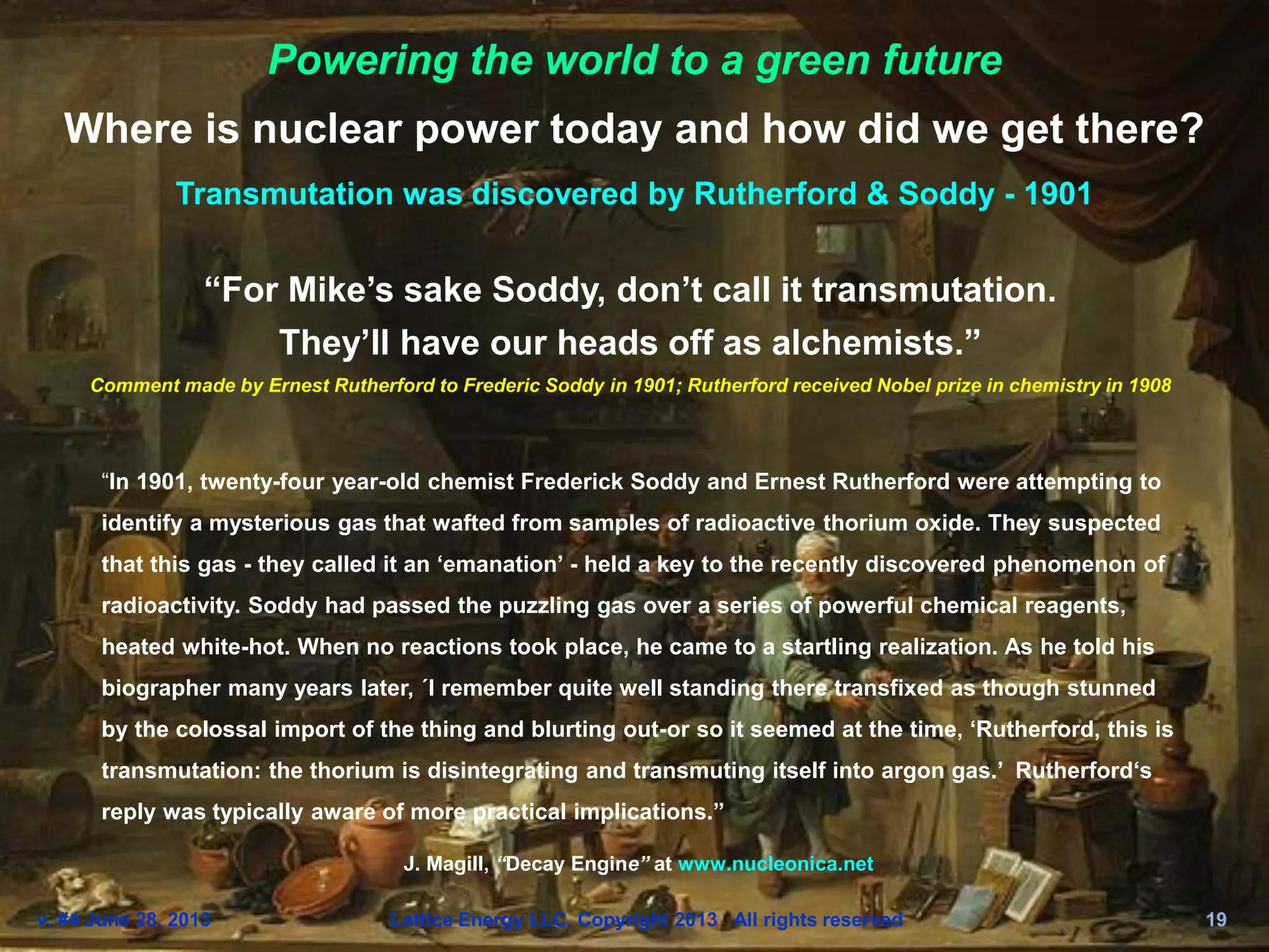
Photographic plate made by Henri Becquerel shows effects of its exposure to radioactivity. A metal Maltese cross, placed between the plate and radioactive uranium salt (potassium uranyl sulfate), left a clearly visible shadow on surface of the (very light grey) photographic plate.



See faint, lighter-grey shadow in shape of a Maltese cross against darker local background

Credit: Henri Becquerel

"Sur les radiations emises par phosphorescence"
Henri Becquerel, *Comptes Rendus* 122 pp. 420 - 421 (1896)
http://gallica.bnf.fr/ark:/12148/bpt6k30780/f422.chemindefer



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Where is nuclear power today and how did we get there?

Transmutation was discovered by Rutherford & Soddy - 1901

> **"For Mike's sake Soddy, don't call it transmutation.**
> **They'll have our heads off as alchemists."**

Comment made by Ernest Rutherford to Frederic Soddy in 1901; Rutherford received Nobel prize in chemistry in 1908

"In 1901, twenty-four year-old chemist Frederick Soddy and Ernest Rutherford were attempting to identify a mysterious gas that wafted from samples of radioactive thorium oxide. They suspected that this gas - they called it an 'emanation' - held a key to the recently discovered phenomenon of radioactivity. Soddy had passed the puzzling gas over a series of powerful chemical reagents, heated white-hot. When no reactions took place, he came to a startling realization. As he told his biographer many years later, ´I remember quite well standing there transfixed as though stunned by the colossal import of the thing and blurting out-or so it seemed at the time, 'Rutherford, this is transmutation: the thorium is disintegrating and transmuting itself into argon gas.' Rutherford's reply was typically aware of more practical implications."

J. Magill, *"Decay Engine"* at www.nucleonica.net

Where is nuclear power today and how did we get there?

Millikan suggested that transmutations occur in stars - 1923

> **“Has nature a way of making these transmutations in her laboratories? She is doing it under our eyes in the radioactive process … Does the process go on in both directions, heavier atoms being continually formed, as well as continually disintegrating into lighter ones? Not on earth, so far as we can see. Perhaps in God’s laboratories, the stars. Some say we shall be finding out.”**

“Gulliver’s travels in science”
R. Millikan, Nobel prize in physics, 1923
Scribner’s **pp. 577 - 585 (Nov. 1923)**
http://www.unz.org/Pub/Scribners-1923nov-00577

Credit: Roberto Porto

Powering the world to a green future

Where is nuclear power today and how did we get there?

Atkinson & Houtermans theorized that light elements can fuse - 1929

Comments about this groundbreaking paper in which stellar thermonuclear reactions were calculated for the very first time:

"The Houtermans-Atkinson theory was a quantitative theory based on the most recent quantum mechanical knowledge. The theory counts among the pioneering contributions to modern astrophysics, but at first it attracted little attention."

H. Kragh, "Quantum Generations", pp. 183 (2002)

"After Gamov had presented his theory, in which two nuclei can interact in spite of the Coulomb repulsion by virtue of the tunnel effect, it was realized by Atkinson and Houtermans that the thermal energy of protons in the centre of the sun was sufficient to provoke nuclear reactions. The physical possibility of thermonuclear reaction in the interior of stars was established."

S. Brandt, "The Harvest of a Century", pp. 259 (2009)

"Zur Frage der Aufbaumöglichkeit der Elemente in Sternen"
Robert Atkinson and Freidrich Houtermans
***Zeitschrift für Physik* 54 pp. 656 - 665 (1929)**

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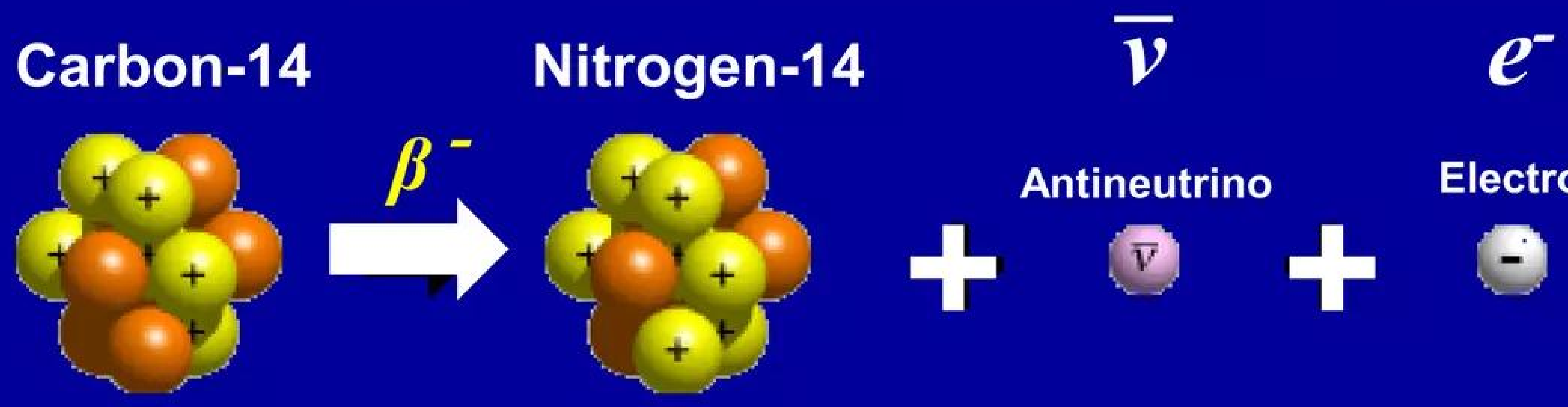
Where is nuclear power today and how did we get there?

Fermi published breakthrough theory of beta-decay with neutrinos - 1934

Beta-minus decay: one neutron spontaneously converts into a proton

Unstable neutron-rich isotopes



Nucleus composed of:

6 protons
8 neutrons

7 protons
7 neutrons

Operates 'south' of valley of stability

Beta-plus decay: one proton spontaneously converts into a neutron

Unstable neutron-poor isotopes

Nucleus composed of:

6 protons
4 neutrons

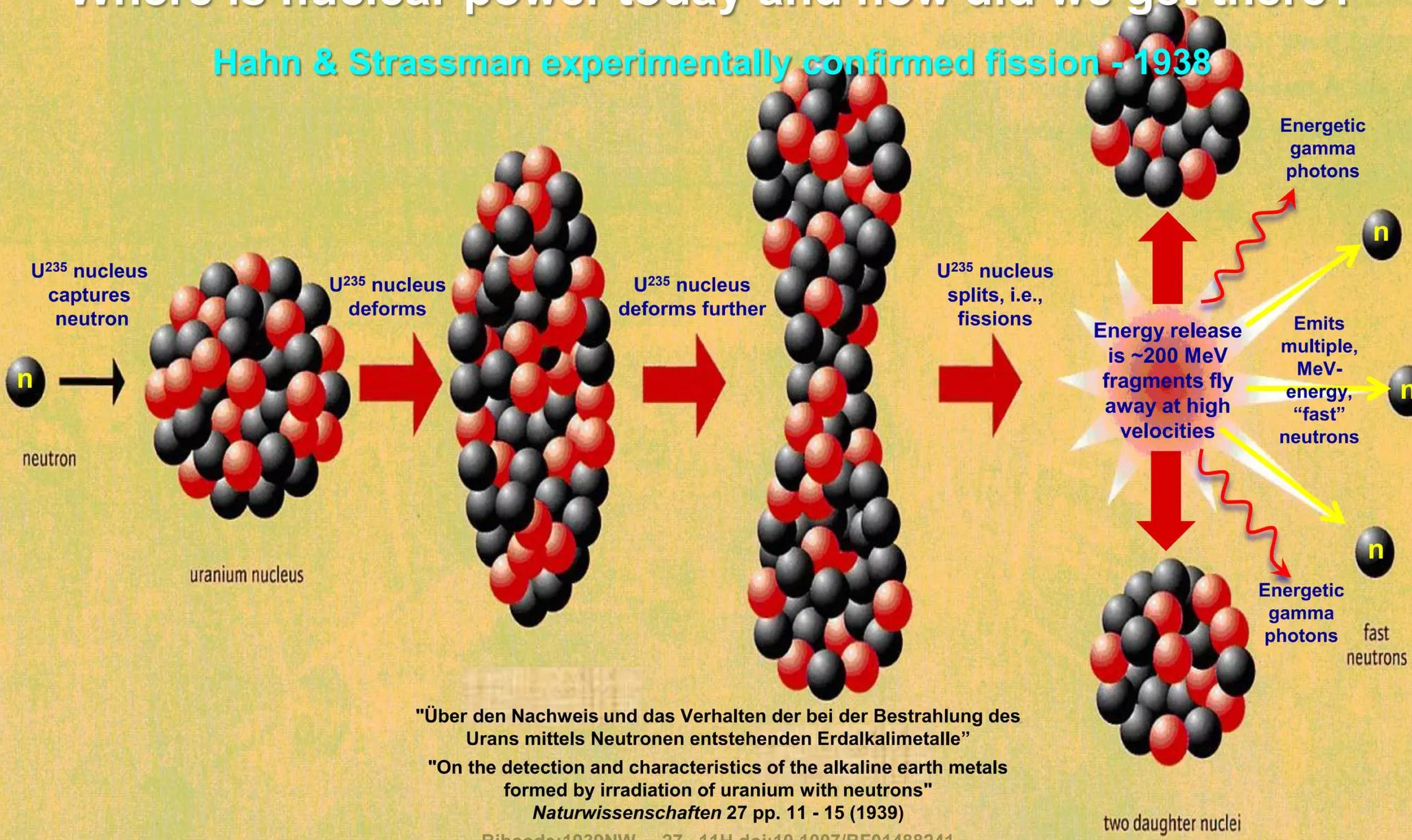
5 protons
5 neutrons

Operates 'north' of valley of stability

"Versuch einer Theorie der β-Strahlen. I"
Enrico Fermi
Zeitschrift für Physik 88 pp. 161 - 177 (1934)

Where is nuclear power today and how did we get there?

Hahn & Strassman experimentally confirmed fission - 1938



U^{235} nucleus captures neutron

U^{235} nucleus deforms

U^{235} nucleus deforms further

U^{235} nucleus splits, i.e., fissions

Energy release is ~200 MeV fragments fly away at high velocities

Energetic gamma photons

Emits multiple, MeV-energy, “fast” neutrons

Energetic gamma photons

"Über den Nachweis und das Verhalten der bei der Bestrahlung des Urans mittels Neutronen entstehenden Erdalkalimetalle”

"On the detection and characteristics of the alkaline earth metals formed by irradiation of uranium with neutrons"

Naturwissenschaften 27 pp. 11 - 15 (1939)

Bibcode:1939NW.....27...11H.doi:10.1007/BF01488241

Powering the world to a green future

Where is nuclear power today and how did we get there?

Bethe theorized that nuclear fusion powers stars - 1939

“It is shown that the most important source of energy in ordinary stars is the [fusion = +] reactions of carbon and nitrogen with protons. These reactions form a cycle in which the original nucleus is reproduced, *viz.* $C^{12} + H = N^{13}$, $N^{13} = C^{13} + e^{+}$, $C^{13} + H = N^{14}$, $N^{14} + H = O^{15}$, $O^{15} = N^{15} + e^{+}$, $N^{15} + H = C^{12} + He^{4}$. Thus carbon and nitrogen merely serve as catalysts for the combination of four protons [H] (and two electrons) into an α-particle [He^{4}]. The carbon-nitrogen reactions are unique in their cyclical character.”

“The agreement of the carbon-nitrogen reactions with observational data is excellent. In order to give the correct energy evolution in the sun, the central temperature of the sun would have to be 18.5 million degrees while integration of the Eddingston equations gives 19 … For fainter stars with lower central temperatures, the [fusion] reaction $H + H = D + e^{+}$ and the reactions following it, are believed to be mainly responsible for the energy production. It is shown further that no elements heavier than He^{4} can be built up in ordinary stars … Production of neutrons in stars is likewise negligible. The heavier elements found in stars must therefore have existed already when the star was formed.”

“Energy production in stars”
Hans Bethe
***Physical Review* 55 pp. 434 - 456 (1939)**
http://prola.aps.org/pdf/PR/v55/i5/p434_1

Powering the world to a green future

Where is nuclear power today and how did we get there?

Highly subjective chronology of key events from 1942 up through 2012

1942 – Enrico Fermi activated Manhattan Project's first working fission reactor at Univ. of Chicago
1945 – US first to use nuclear weapons in war; destroyed cities of Hiroshima and Nagasaki in Japan
1946 – F. Hoyle first published *e* + *p* neutronization reaction theorized in cores of dying stars
1951 – A. Einstein, H. Bethe & E. Sternglass reviewed apparent *e* + *p* reaction in tabletop apparatus
1952 – US detonated first fission-fusion thermonuclear weapon at Eniwetok Island, South Pacific
1955 – First commercial fission-based nuclear power reactor in Shippingport, Pennsylvania, USA
1957 – M. & G. Burbidge, W. Fowler & F. Hoyle published paper delineating modern astrophysics
1965 – M. & G. Burbidge, W. Fowler & F. Hoyle published paper suggesting ex-core nucleosynthesis
1960s – S. Glashow, A. Salam & S. Weinberg published modern theory of electroweak interaction
1970 thru early 1980s – Glashow-Salam-Weinberg's electroweak theory confirmed experimentally
1985 – ITER fusion power generation project first began at 1985 superpower summit in Geneva
1986 – K. Erik Drexler published "Engines of Creation: The Coming Era of Nanotechnology"
1989 – S. Pons & M. Fleischmann "cold fusion" debacle began with Univ. of Utah press conference
2001 – Lattice Energy LLC commenced operation to commercialize LENRs for power generation
2005 – A. Widom & L. Larsen released first theoretical preprint re LENRs on Cornell physics arXiv
2006 – A. Widom & L. Larsen published 'core' of LENR theory in the *European Physical Journal C*
2010 – ITER began 10-year construction phase with estimated completion costs of 13 billion Euros
2010 – Y. Srivastava, A. Widom & L. Larsen published theory paper in *Pramana - Journal of Physics*
2012 – CERN sponsored first-ever colloquium on LENRs with Y. Srivastava discussing W-L theory
2012 – American Nuclear Society sponsored first working session on LENRs to be held in 16 years

Powering the world to a green future

Nuclear martial arts: fusion taekwondo vs. LENR aikido

Fissio/fusion are few-body taekwondo; LENRs are many-body aikido

Taekwondo = Fission and esp. fusion

‘Hard’ way: directs focused kinetic energy onto target

Requires great physical strength

Mainly two-body or few-body

Defeats only one opponent at a time

Video: http://www.youtube.com/watch?v=yIawbHsotgI

‘Brute force’ utilization of a defender’s input energy

Aikido = LENRs

‘Gentle’ way: ‘borrows’ kinetic energy from targets

Decidedly many-body

Requires little physical strength

Defeats two or more opponents simultaneously

Video: http://www.youtube.com/watch?v=pk9DTiyPtmo

‘Smart’ utilization of a defender’s limited input energy

Aikido (Japanese: 合気道 Hepburn: *Aikidō*) [a.i.ki.doː] is a Japanese martial art developed by Morihei Ueshiba as a synthesis of his martial studies, philosophy, and religious beliefs. Aikido is often translated as "the Way of unifying (with) life energy” or as "the Way of harmonious spirit." Ueshiba's goal was to create an art that practitioners could use to defend themselves while also protecting their attacker from injury. Aikido is performed by blending with the motion of the attacker and redirecting the force of the attack rather than opposing it head-on. This requires very little physical strength, as the *aikidōka* (aikido practitioner) "leads" the attacker's momentum using entering and turning movements. The techniques are completed with various throws or joint locks. Aikido derives mainly from the martial art of Daitō-ryū Aiki-jūjutsu, but began to diverge from it in the late 1920s, partly due to Ueshiba's involvement with the Ōmoto-kyō religion. Ueshiba's early students' documents bear the term *aiki-jūjutsu*. [source: Wikipedia]

Taekwondo taɪˌkwɒnˈdoʊ (Korean 태권도 (跆拳道) [tʰɛk̚wʌndo]) is a martial art originating in Korea. It combines combat and self-defense techniques with sport and exercise. In Korean, *tae* (태, 跆) means "to strike or break with foot"; *kwon* (권, 拳) means "to strike or break with fist"; and *do* (도, 道) means "way", "method", or "path". Thus, *taekwondo* may be loosely translated as "the way of the foot and the hand." Although there are doctrinal and technical differences between sparring in the two main styles and among the various organizations, the art in general emphasizes kicks thrown from a mobile stance, employing the leg's greater reach and power (compared to the arm). Taekwondo training generally includes a system of blocks, kicks, punches, and open-handed strikes and may also include various take-downs or sweeps, throws, and joint locks. [source: Wikipedia]

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Nuclear martial arts: fusion taekwondo vs. LENR aikido

$e^- + p^+ \rightarrow n + v$ in condensed matter requires aikido physics

Don’t need taekwondo (enormous million$^+$- degree temperatures) to trigger LENRs

- ✓ **Prior to advent of Widom-Larsen theory, astrophysicists thought that “neutronization” (direct $e^- + p^+$ reaction) only occurred deep in stellar cores during supernova detonations**
- ✓ **No “new physics” in *any* of this: all we did was integrate many-body collective effects with modern electroweak theory under the ‘umbrella’ of the Standard Model; vast amount of supporting experimental data**
- ✓ **Without many-body collective effects + condensed matter quantum mechanical effects (= aikido) none of this could ever occur at substantial rates at moderate temperatures/pressures in chemical cells**

“Toto, I have the feeling we're not in Kansas anymore.“

Dorothy in *The Wizard of Oz* (1939)

“There is nothing as deceptive as an obvious fact.”

Sherlock Holmes, *The Boscombe Valley Mystery* (1891)

"These are very deep waters."

Sherlock Holmes, *The Adventure of the Speckled Band* (1892)

“ … when you have eliminated the impossible, whatever remains, however improbable, must be the truth.”

Sherlock Holmes, *The Sign of the Four* (1890)

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Nuclear martial arts: fusion taekwondo vs. LENR aikido

$e^- + p^+ \rightarrow n + v$ in stars requires mega-scale taekwondo

Unlike dying stars, LENRs don’t need macroscopic taekwondo to trigger $e^- + p^+$ reaction

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

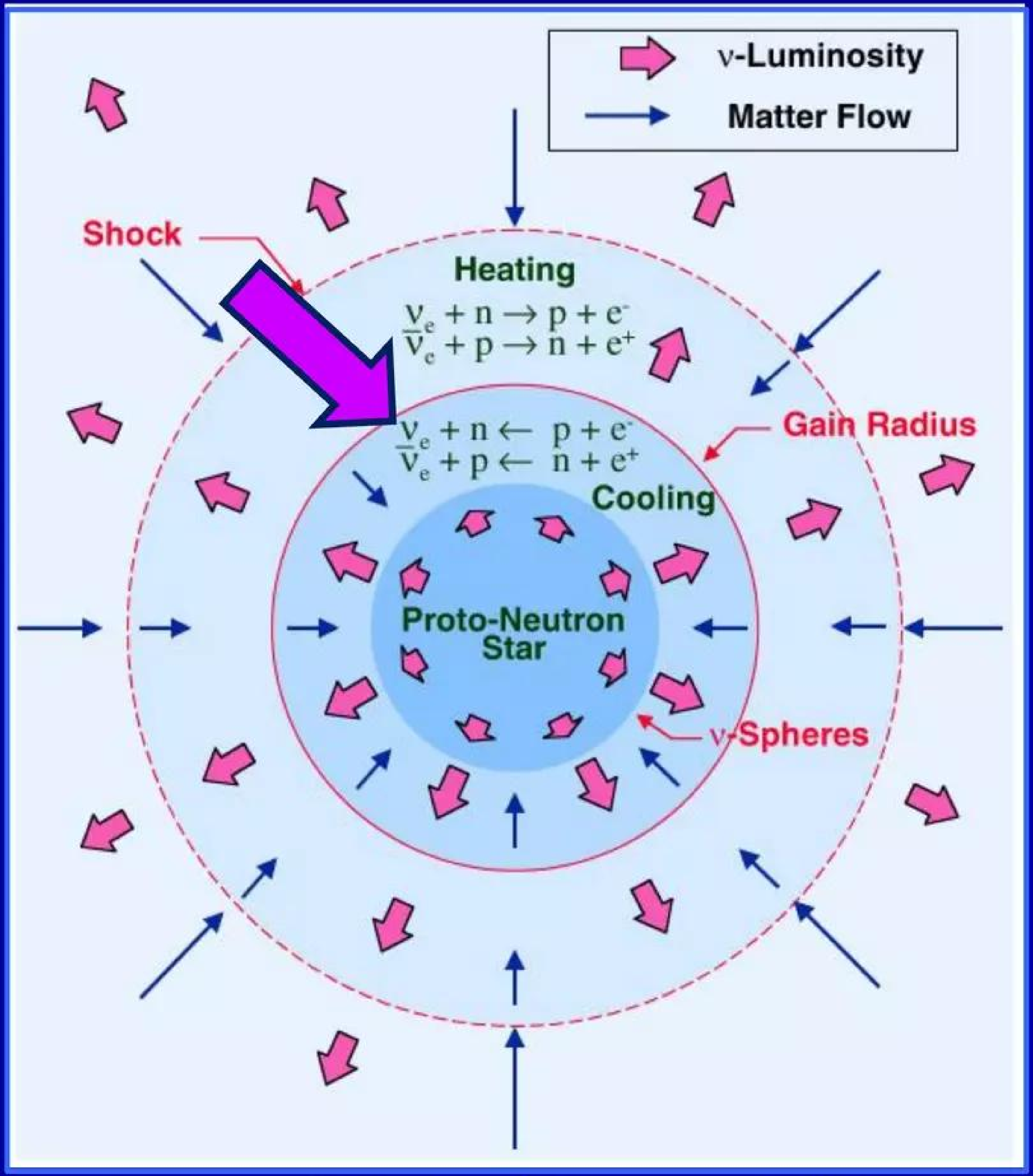
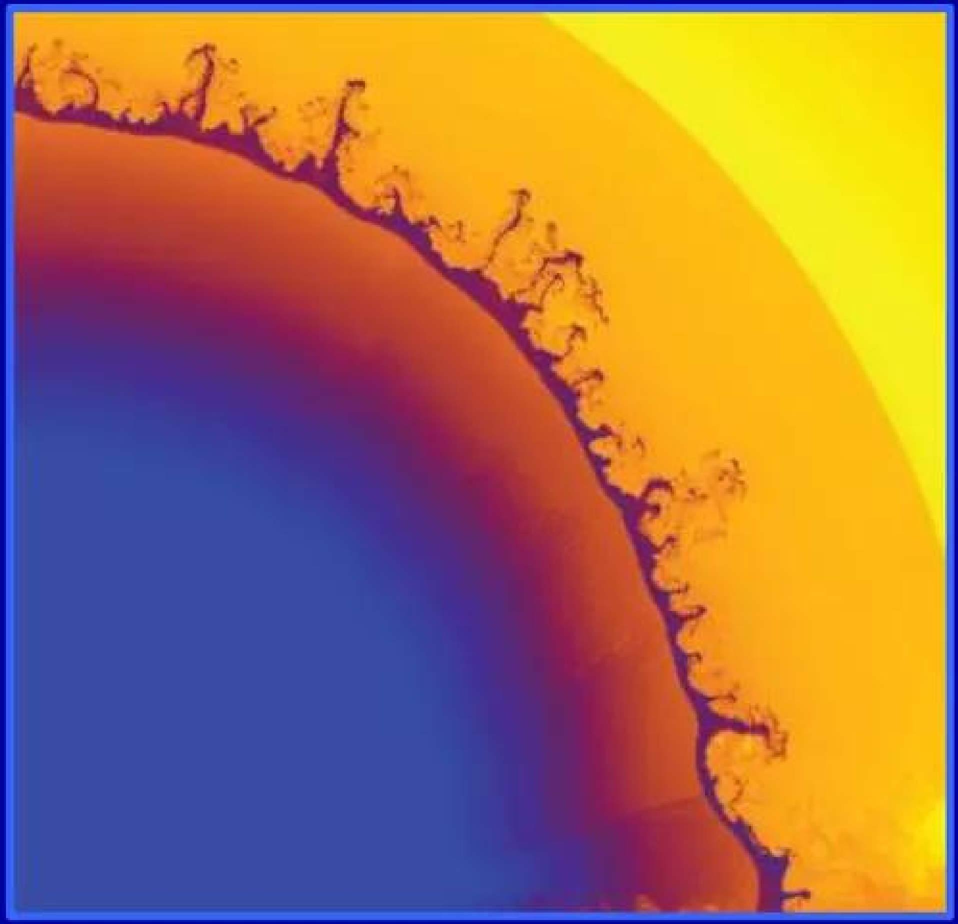


Image credit: TeraScale Supernova Initiative



“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.”

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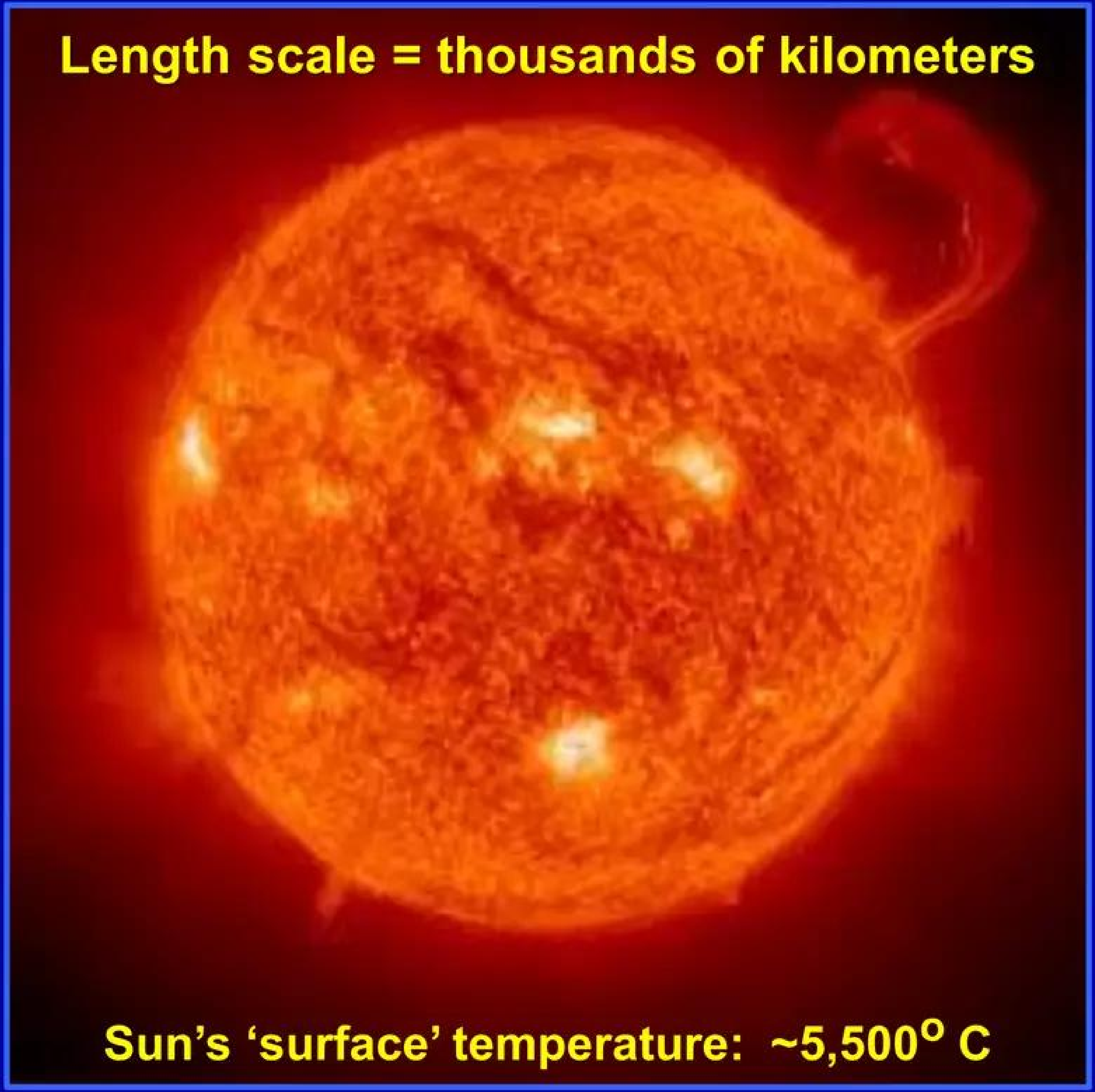
Nuclear martial arts: fusion taekwondo vs. LENR aikido

Nature's mega-taekwondo: thermonuclear fusion in stars

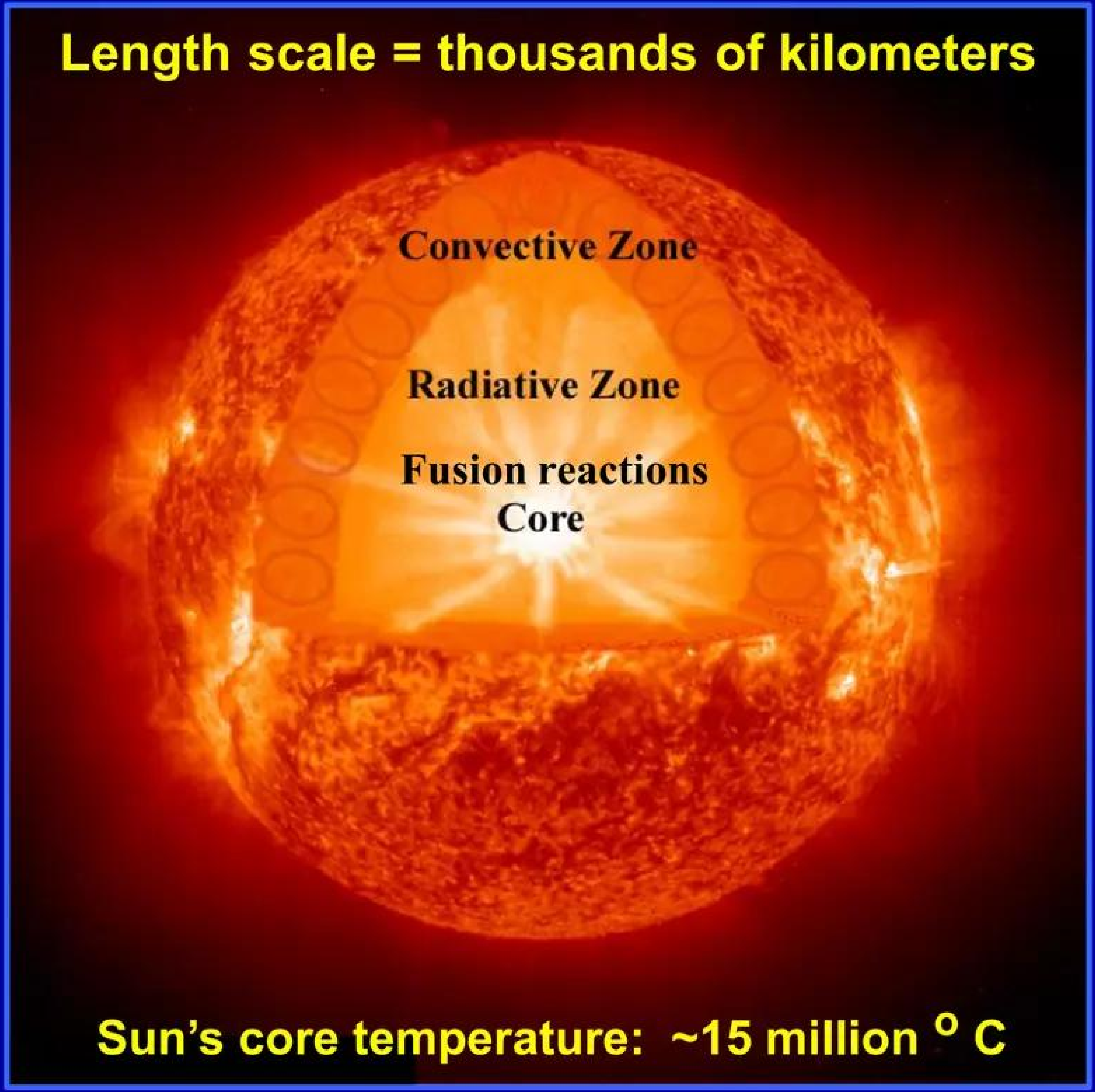
Triggering H-H (i.e., p^+-p^+) fusion in stars requires enormous temperatures and plasma structures

Earth's sun is a smallish, long-lived G-type yellow dwarf star that fuses hydrogen in p^+-p^+ reactions



Length scale = thousands of kilometers

Sun's 'surface' temperature: ~5,500° C



Length scale = thousands of kilometers

Sun's core temperature: ~15 million ° C

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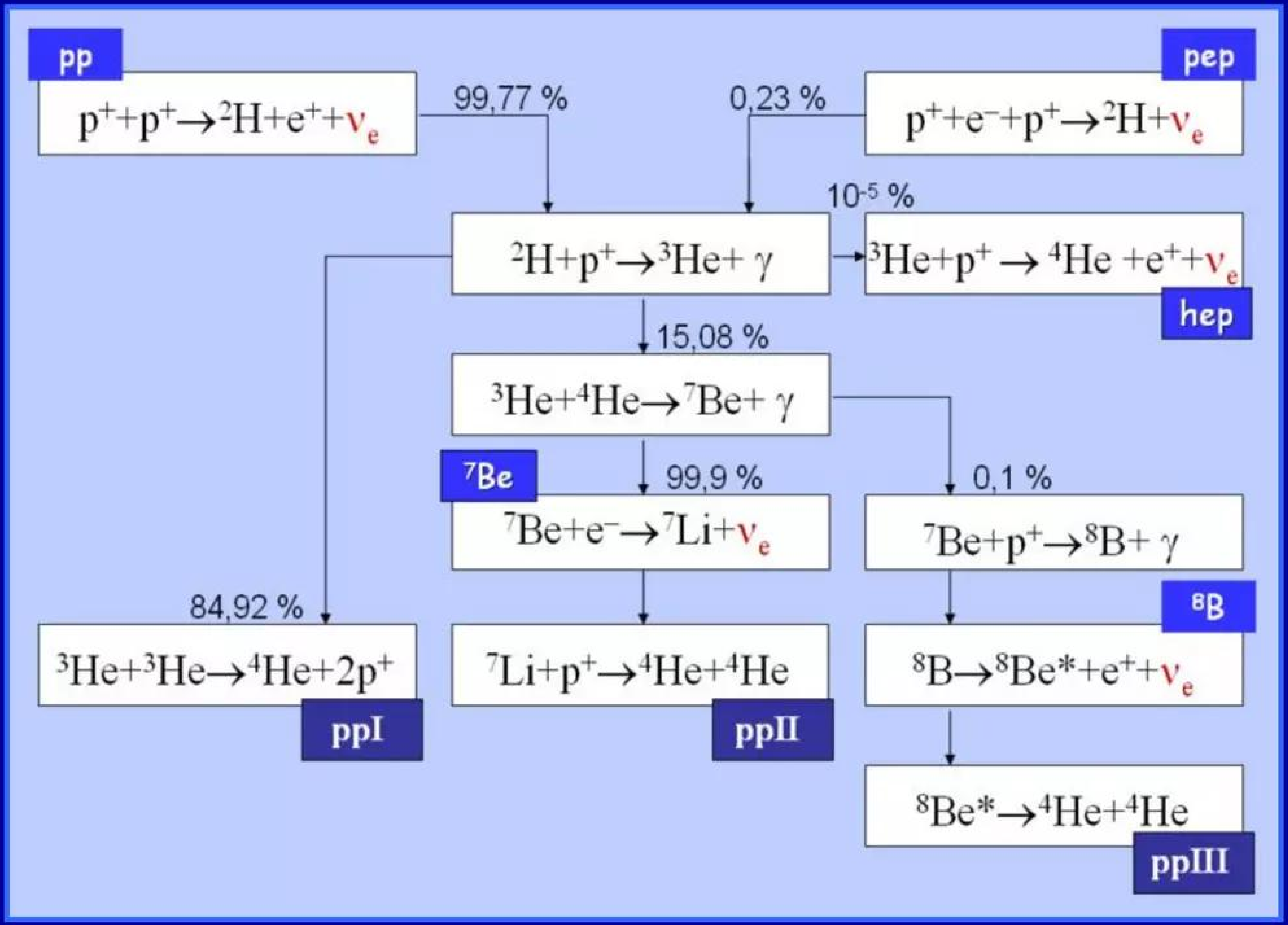
Nuclear martial arts: fusion taekwondo vs. LENR aikido

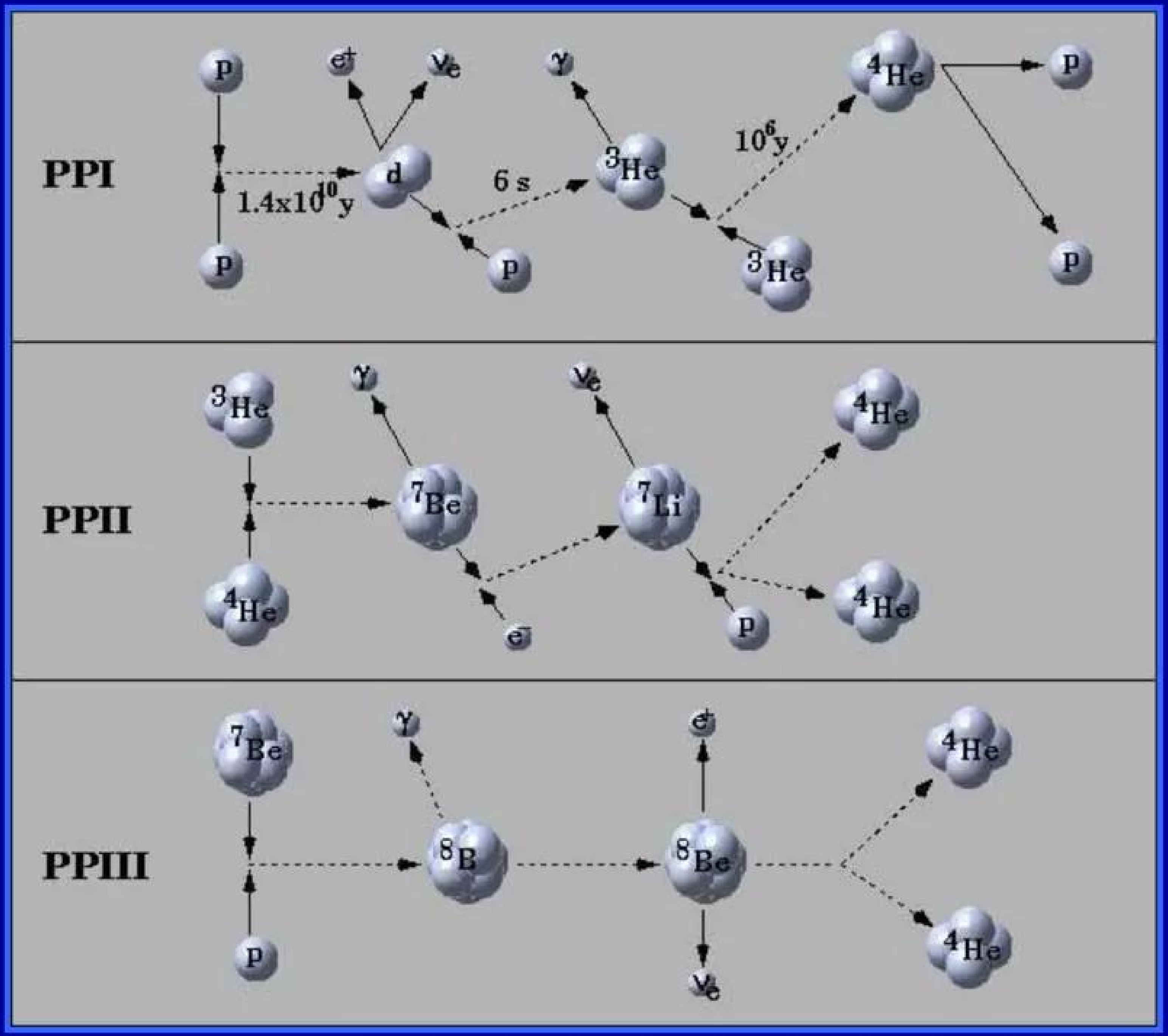
Nature's mega-taekwondo: p^+-p^+ fusion in the innermost core of Earth's sun

Current astrophysical thinking: this type of fusion reaction produces energy in Sun and smaller stars

Key point: 99% of Sun's thermonuclear fusion reactions occur within its dense, super-hot core

Summary of main types of hypothesized stellar p^+-p^+ charged particle fusion reactions in Sun:





Source: Wikipedia as of May 17, 2011

Credit: Prof. Vik Dhillon

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Nuclear martial arts: fusion taekwondo vs. LENR aikido

Nature's mega-taekwondo: p^+-p^+ fusion in the innermost core of Earth's sun

Computer model of the Sun at 4.5 billion years; core generates ~99% of its total fusion power

% of radius	Radius (10^9 m)	Temperature (10^6 K)	% Luminosity	Fusion Rate (joules/kg-sec)	Fusion Power Density (joules/sec-m^3)
0	0.00	15.7	0	0.0175	276.5
9	0.06	13.8	33	0.010	103.0
12	0.08	12.8	55	.0068	56.4
14	0.10	11.3	79	.0033	19.5
19	0.13	10.1	91	.0016	6.9
22	0.15	9.0	97	0.0007	2.2
24	0.17	8.1	99	0.0003	0.67
29	0.20	7.1	100	0.00006	.09
46	0.32	3.9	100	0	0
69	0.48	1.73	100	0	0
89	0.62	0.66	100	0	0

Core

From: B. Stromgrew (1965) reprinted in D. Clayton, "Principles of Stellar Evolution and Nucleosynthesis". New York: McGraw-Hill (1968)

Online source of Table: http://fusedweb.llnl.gov/CPEP/Chart_Pages/5.Plasmas/SunLayers.html

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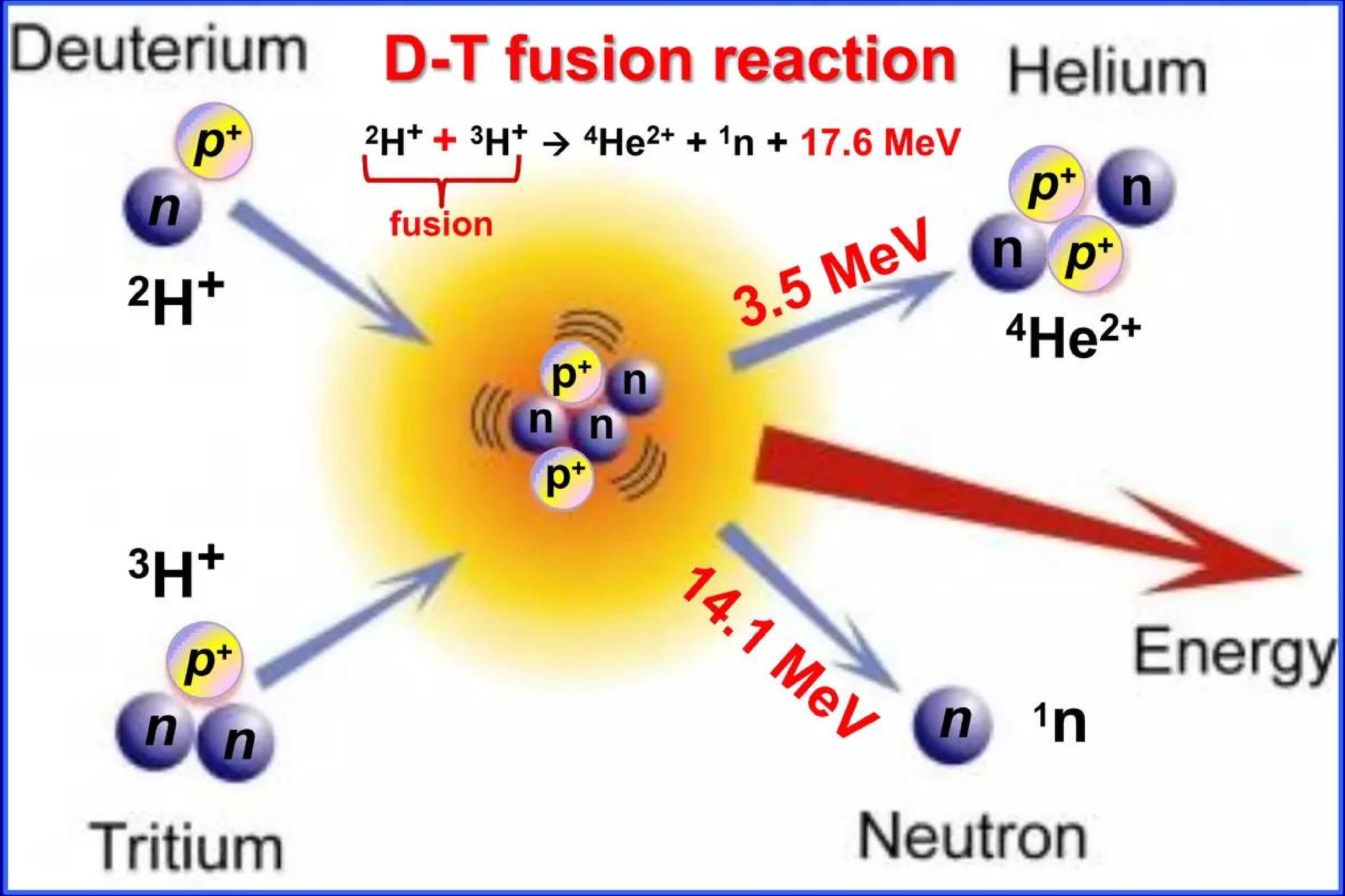
Nuclear martial arts: fusion taekwondo vs. LENR aikido

Earthly nuclear taekwondo: D-T fusion reaction

Triggering D-T fusion on Earth requires enormous temperatures and gigantic equipment

This is the 'Holy Grail' of government fusion research pursued since 1950s

Note: D-T reaction produces very energetic 14.1 MeV neutrons



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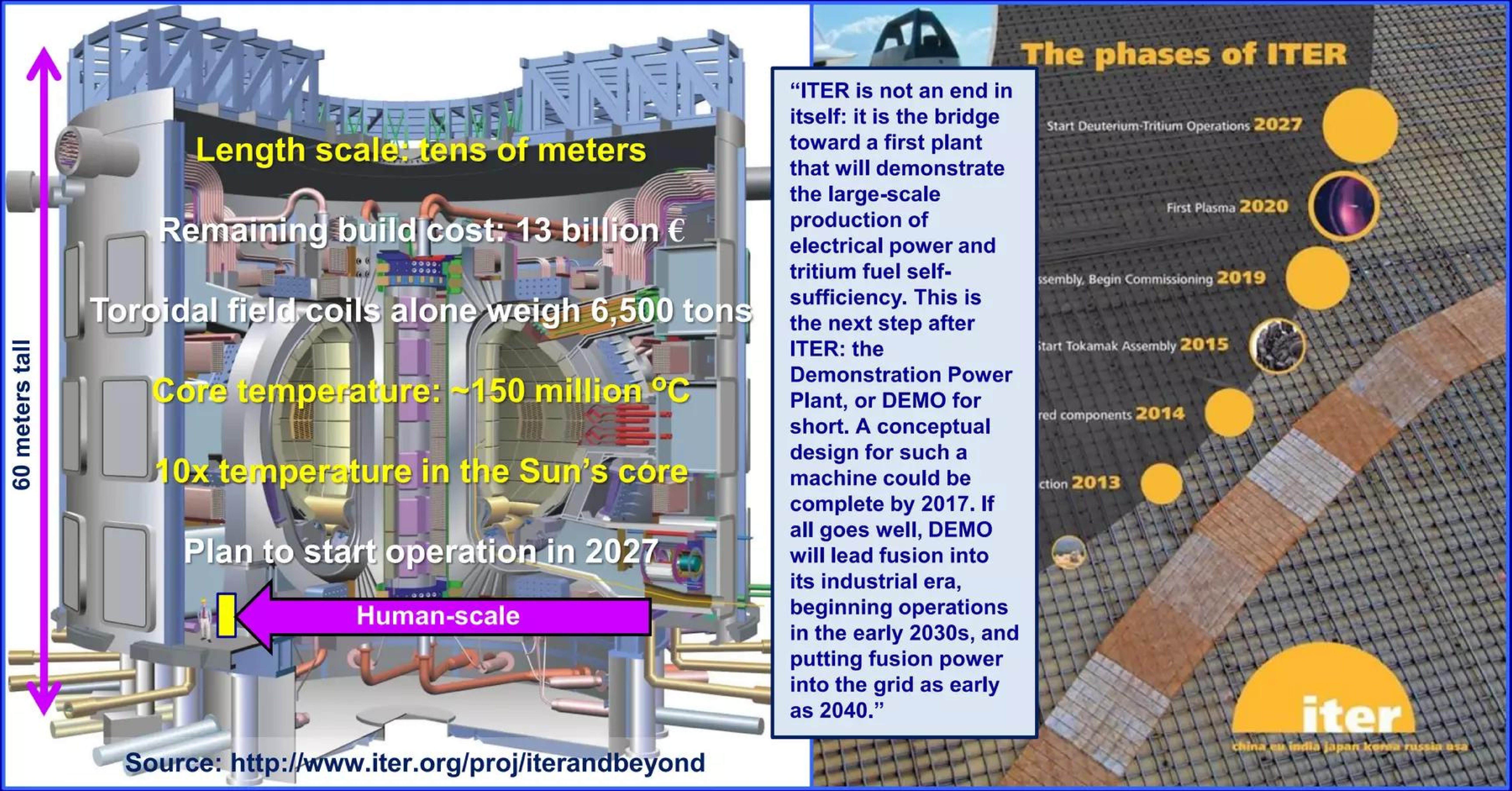
Nuclear martial arts: fusion taekwondo vs. LENR aikido

Earthly nuclear taekwondo: D-T tokamak fusion in ITER

If successful, in 2027 will produce 500 MW electrical output from 50 MW input power

ITER reactor is located at facility in Cadarache, France



Length scale: tens of meters

Remaining build cost: 13 billion €

Toroidal field coils alone weigh 6,500 tons

Core temperature: ~150 million °C

10x temperature in the Sun's core

Plan to start operation in 2027

"ITER is not an end in itself: it is the bridge toward a first plant that will demonstrate the large-scale production of electrical power and tritium fuel self-sufficiency. This is the next step after ITER: the Demonstration Power Plant, or DEMO for short. A conceptual design for such a machine could be complete by 2017. If all goes well, DEMO will lead fusion into its industrial era, beginning operations in the early 2030s, and putting fusion power into the grid as early as 2040."

Source: http://www.iter.org/proj/iterandbeyond

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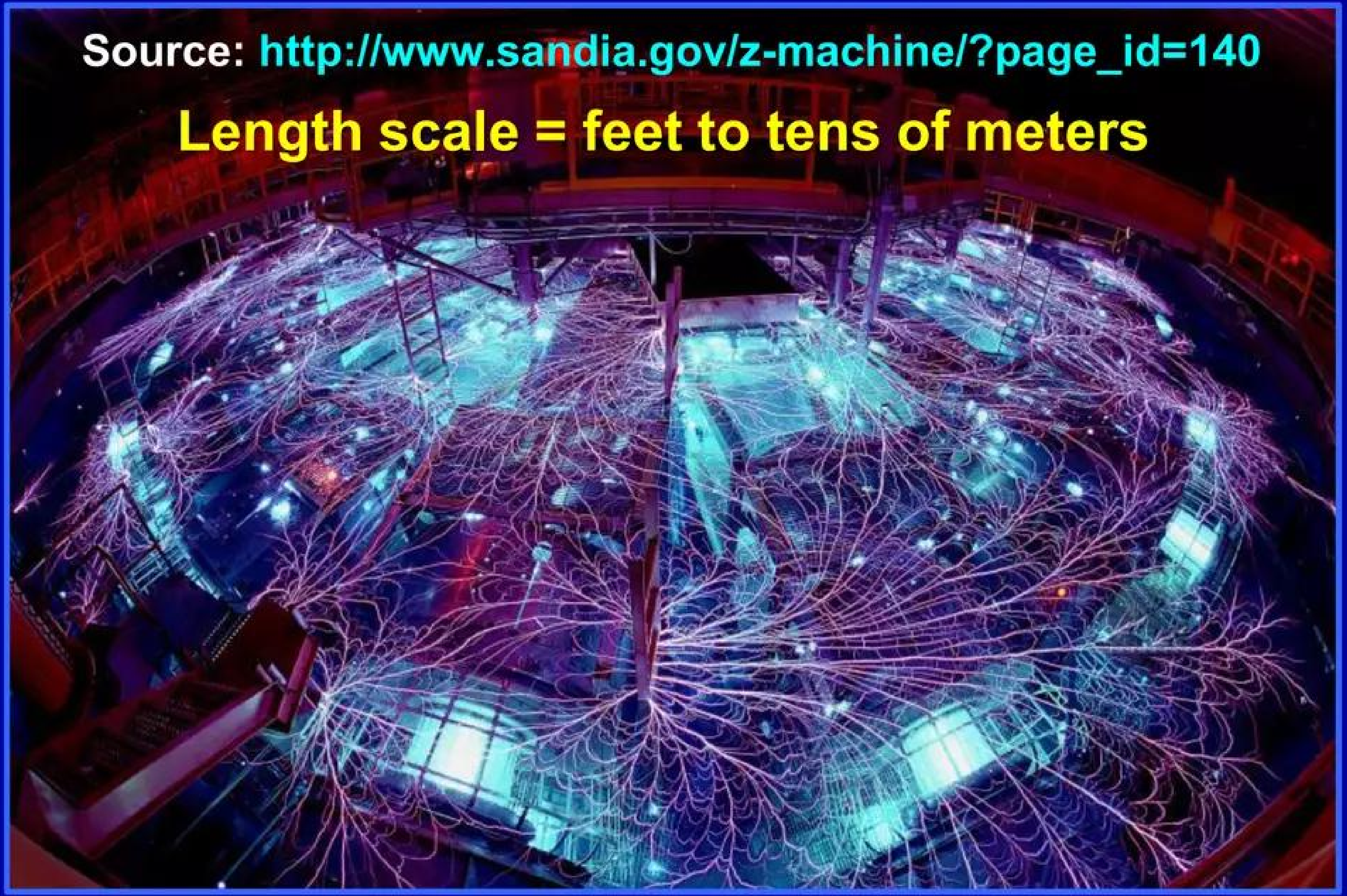
Nuclear martial arts: fusion taekwondo vs. LENR aikido

Earthly nuclear taekwondo: Z-pinch and ICF fusion methods

Input energy: huge pulsed 26 million Ampere electrical current

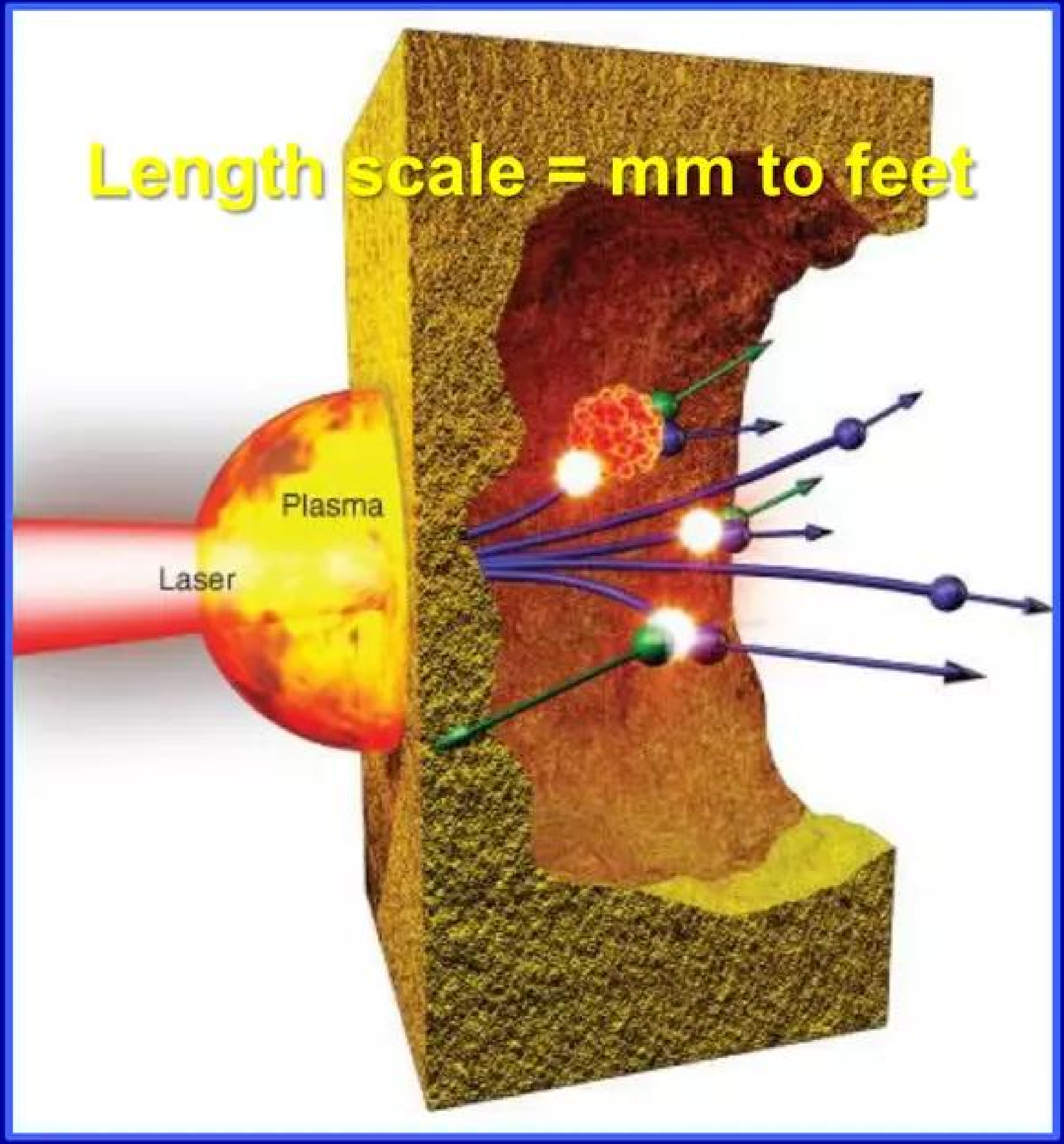
Z-pinch machine
Sandia National Laboratories (USA)



"The Z machine is the Earth's most powerful and efficient laboratory radiation source. To scientists, this means that in each of the approximately 200 shots Z fires every year, the machine uses currents of about 26 million amps to reach peak X-ray emissions of 350 terawatts and an X-ray output of 2.7 megajoules … can create conditions found nowhere else on Earth … Pulsed power is a technology that concentrates electrical energy and turns it into short pulses of enormous power, which are then used to generate X-rays and gamma rays … [its] controlled radiation creates conditions similar to those caused by the detonation of nuclear weapons, which is why from its earliest days pulsed power has been used to study weapons effects."

Input energy: gigajoule pulse of E-M laser photons

National Ignition Facility Laser (NIF) - ICF
Lawrence Livermore National Laboratory (USA)



"In positron generation experiments, the short-pulse Titan laser fires a tightly focused 'photon bullet' at a tiny gold disk. The laser tears electrons from their atoms and accelerates them through the gold target. As high-energy electrons interact with the gold nuclei, they are transformed into a lower energy electron (green) and its mirror, a positron (purple). (Rendering by Kwei-Yu Chu.)"

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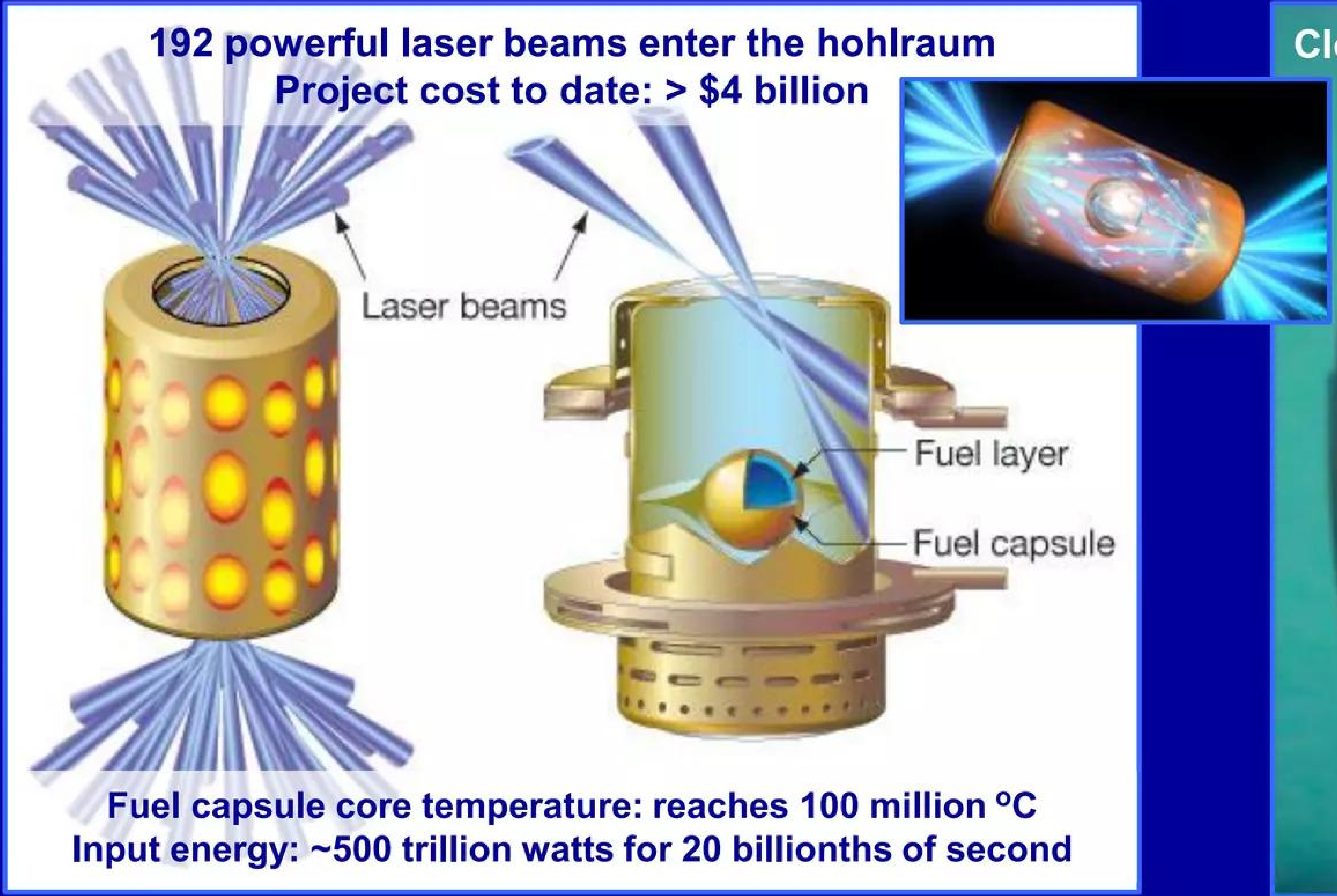
Nuclear martial arts: fusion taekwondo vs. LENR aikido

Earthly taekwondo: ICF fusion - National Ignition Facility (LLNL)

Sources: https://lasers.llnl.gov/programs/nic/icf/ and https://lasers.llnl.gov/programs/nic/icf/how_icf_works.php



192 powerful laser beams enter the hohlraum
Project cost to date: > $4 billion

Fuel capsule core temperature: reaches 100 million ^{o}C
Input energy: ~500 trillion watts for 20 billionths of second

Close-up of Gold hohlraum 'target'

Tiny fuel capsule

"All of the energy of NIF's 192 beams is directed inside a gold cylinder called a hohlraum, which is about the size of a dime. A tiny capsule inside the hohlraum contains atoms of deuterium and tritium that fuel the ignition process … Laser beams rapidly heat the inside surface of the hohlraum … X-rays from the hohlraum compress the fuel capsule … during final part of the [fuel] implosion, the fuel core reaches 20 times the density of Lead and ignites at 100 million ^{o}C … Thermonuclear burn [commences]."

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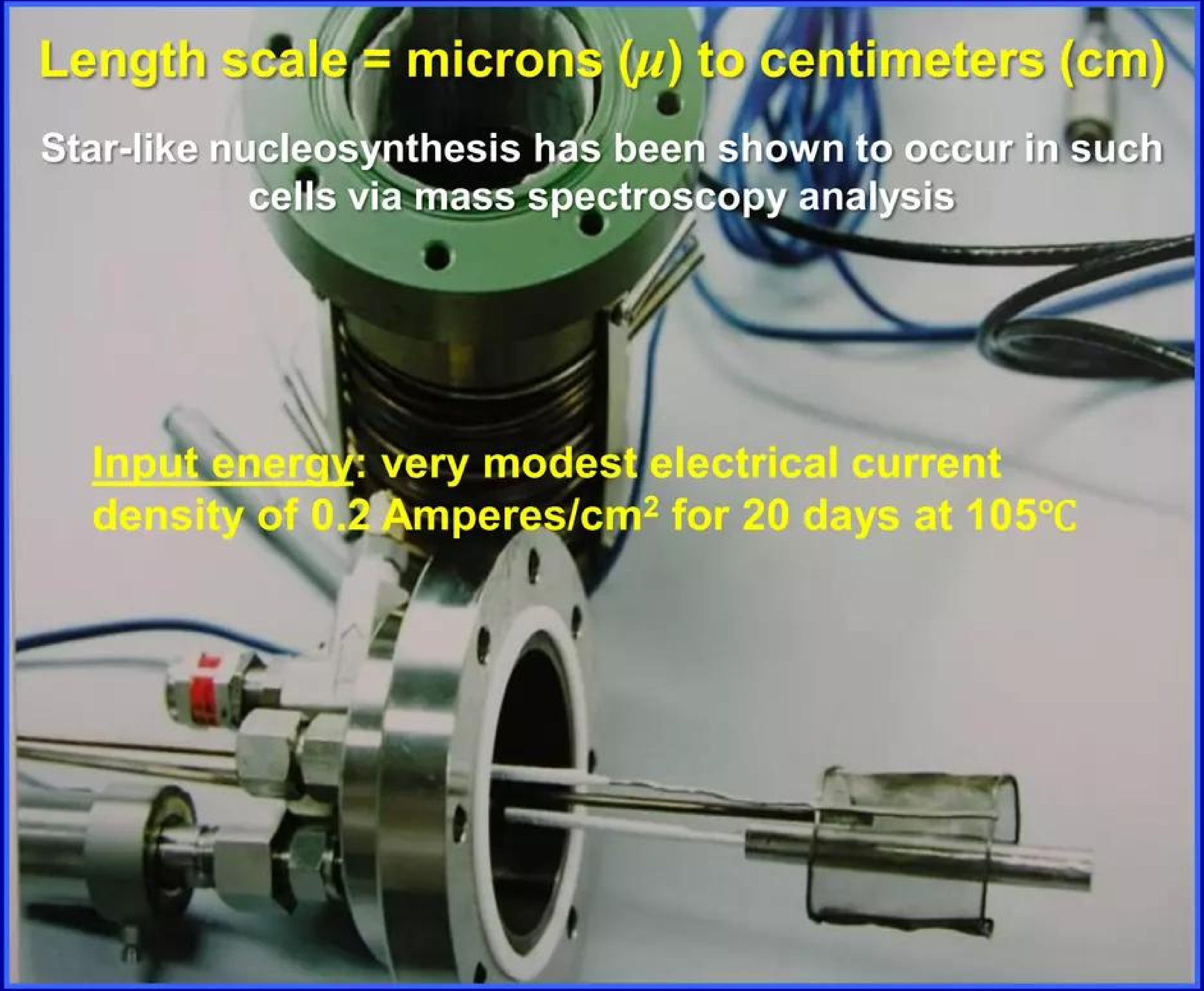
Nuclear martial arts: fusion taekwondo vs. LENR aikido

Earthly micro-/nano-aikido nuclear transmutation: LENRs

Mizuno (Hokkaido Univ., Japan) - electrolytic chemical cell



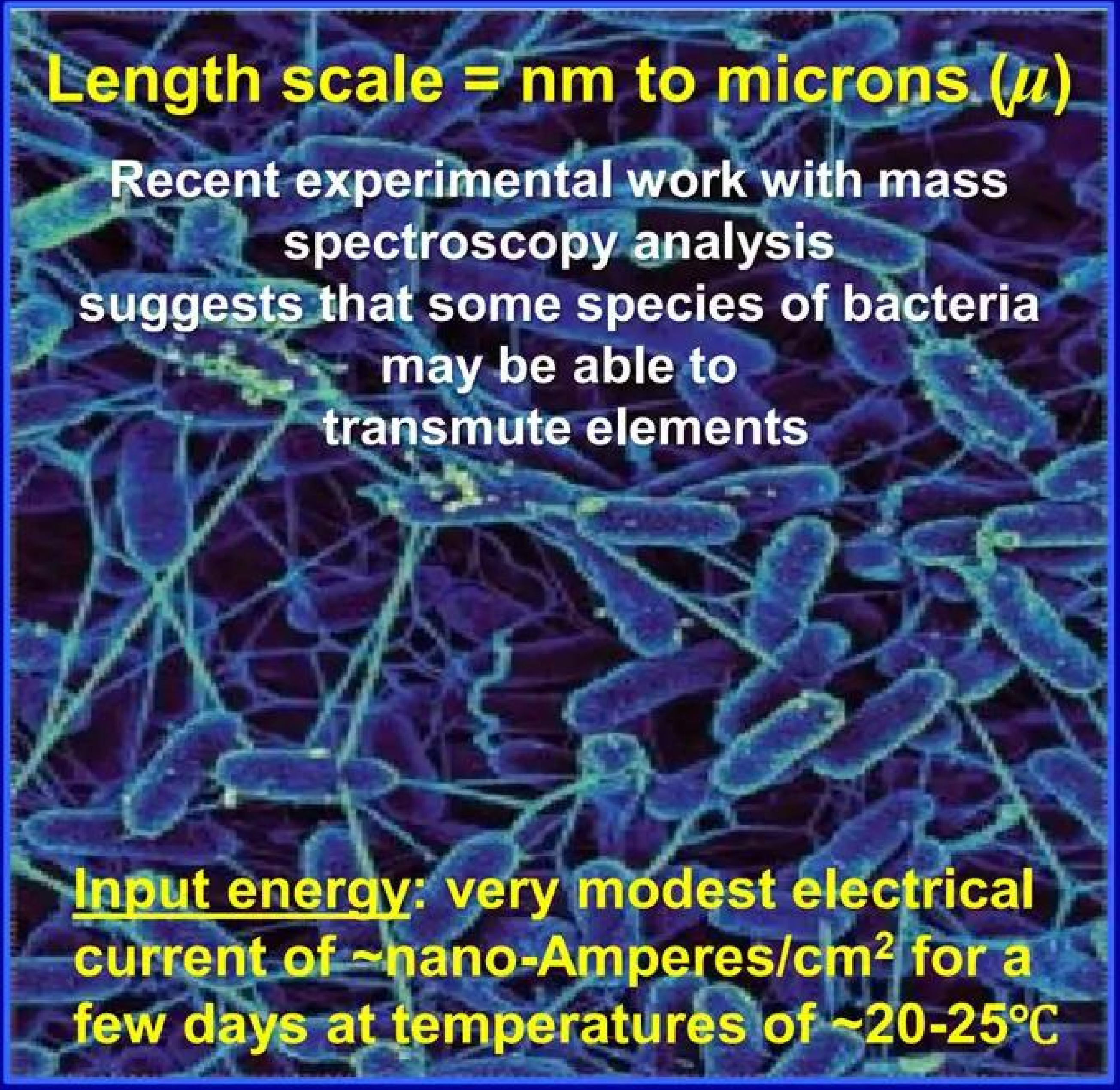
Length scale = microns (μ) to centimeters (cm)

Star-like nucleosynthesis has been shown to occur in such cells via mass spectroscopy analysis

Input energy: very modest electrical current density of 0.2 Amperes/cm^2 for 20 days at 105℃

Quoting from Mizunos’ presentation: electrolysis was performed in a closed cell made from a stainless steel cylinder. The cell has an inner Teflon cell made with 1-mm thick wall and 1 cm thick upper cap; the inner height and diameter are 20 cm and 7 cm, the volume is 770 cm3. Before electrolysis electrolyte were pre-electrolyzed using another Pt mesh electrode. After that the Pt electrode was removed and the palladium rod sample was connected to the electrical terminal. Electrolysis experiments were performed with the current density of 0.2 A/cm2 for 20 days at 105℃.

Shewanella sp. **bacteria with nanowires**



Length scale = nm to microns (μ)

Recent experimental work with mass spectroscopy analysis suggests that some species of bacteria may be able to transmute elements

Input energy: very modest electrical current of ~nano-Amperes/cm^2 for a few days at temperatures of ~20-25℃

Wikipedia: “*Shewanella putrefaciens* is a … bacterium … isolated from marine environments … facultative anaerobe with ability to reduce iron and manganese metabolically; that is, it can use iron and manganese as the terminal electron acceptor in the electron transport chain … also one of the organisms associated with the odor of rotting fish … is one of several species that … derive energy by reducing Uranium(VI) to Uranium (IV) .. thought to be important in making Uranium deposits … strain CN32 is … capable of reducing metals, metalloids, and even radionuclides in place of oxygen during anaerobic metabolism.” growth.”

High local electric fields trigger condensed matter LENRs

LENR aikido only requires modest macroscopic temperatures and tiny devices

Aikido physics on device surfaces enables nuclear-strength, *μ*-scale local E-fields

D. Seidman's candid remarks about electron field emission and breakdown in a grant proposal written back in 2005:

Seidman is the Walter P. Murphy Professor of Materials Science and Engineering at Northwestern University in Evanston, IL, and leads the Seidman Research Group at NWU's Center for Atom-Probe Tomography (NUCAPT) - http://arc.nucapt.northwestern.edu/Seidman_Group

Prof. Seidman has a unique knowledge of high surface electric fields, field emission, and arc discharges as a result of his many years of work with atom-probe tomography (APT) which uses nanoscale local electric fields of 10^{10} V/m *and higher* to image the structure and analyze the chemical composition of surfaces on near atomic-scales (see image to right courtesy of Imago, Inc., a manufacturer of APTs)

Quoting (*ca*. 2005), "NUCAPT is among the world leaders in the field of three-dimensional atom-probe microscopy, particularly as result of the recent installation of a LEAP microscope, manufactured by Imago Scientific Instruments. Currently only three other LEAP microscopes, with a comparable performance, exist throughout the world."

According to Widom-Larsen theory, local field emission and arc-like phenomena may accompany nuclear processes in LENR-active sites

Seidman's quoted remarks were made in the context of a publicly posted 2005 grant proposal: *"Experimental study of high field limits of RF cavities"* D. Seidman and J. Norem

Please see source URL:

http://www.hep.uiuc.edu/LCRD/LCRD_UCLC_proposal_FY05/2_49_Seidman_Norem.pdf

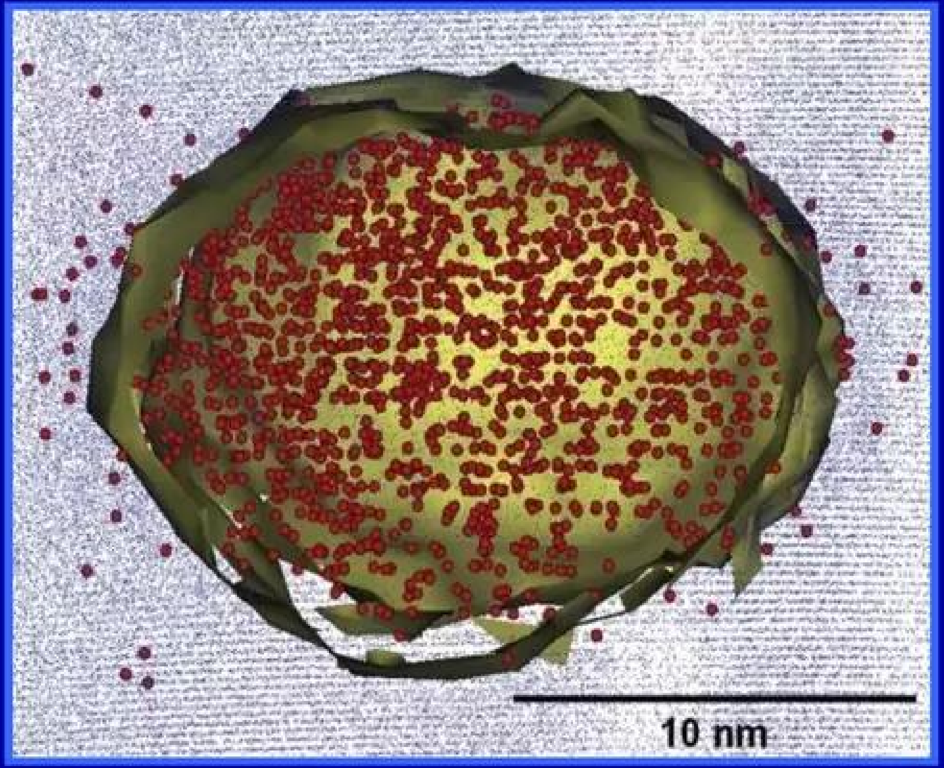


Image: Larson & Kelly, Imago, Inc., local-electrode atom probe image of ordered $L1_2$ Al_3Sc precipitate in aluminum matrix (Al – blue, Sc – red). The <200> planar spacing of the crystalline Al lattice (spacing ~0.2nm) is evident and contrasts with the <100> planar spacing (~0.4 nm) of the Al_3Sc precipitate. Alloy provided by van Dalen, Dun, and Seidman

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High local electric fields trigger condensed matter LENRs

LENR aikido only requires modest macroscopic temperatures and tiny devices

Aikido physics on device surfaces enables nuclear-strength, *μ*-scale local E-fields

Electric breakdown briefly creates local power densities ~ 10^{21} W/m^3:

"[Electric arc] breakdown at surfaces was discovered by Earhart and Michelson, at [the University of] Chicago, in 1900 … While checking the new 'electron' theory of gas breakdown at small distances, they discovered that there were two mechanisms present, at large distances gas breakdown dominated, and at small distances [i.e., on small length-scales] breakdown of the surface was correctly identified as the mechanism. The break point where the two mechanisms met, at atmospheric pressure, occurs at about 300 V … This was confirmed 5 years later by Hobbs and Millikan, and is consistent with modern data on vacuum breakdown."

"Although high electric fields have been used in DC and RF applications for many years, up to now there has been no fundamental agreement on the cause of breakdown in these systems … Until our work, no theoretical understanding of this process developed over the last 100 years, although many papers have been written."

"Another interesting feature of this [electrical breakdown] mechanism is that the power densities involved are enormous. The numbers can be obtained from the values we measured for field emitted currents, electric field, the emitter dimensions, and volume for transferring electromagnetic field energy into electron kinetic energy. Combining these gives, (10 GV/m)(10^{-7} m)(1 mA)/(10^{-7}m)^3 = 10^{21} W/sec·m^3, a value that seems to be greater than all other natural effects, except perhaps Gamma Ray Bursters (GRB's). The power density is comparable to nuclear weapons. Michelson and Millikan noticed the 'hot sparks' in 1905, bought a vacuum pump, (which they didn't have), and invented vacuum ultraviolet spectroscopy. Both moved on, and did not look in detail at the mechanisms involved."

"Experimental study of high field limits of RF cavities" D. Seidman and J. Norem

Again, please refer to source URL:

http://www.hep.uiuc.edu/LCRD/LCRD_UCLC_proposal_FY05/2_49_Seidman_Norem.pdf

In the following Slide, we modify a chart shown in Seidman & Norem's above-noted proposal to illustrate the very approximate regions of physical parameter space in which LENRs may occur if ALL the necessary preconditions that we have previously outlined are obtained. Please note carefully that just the presence of very high local E-M fields by itself does not guarantee that LENRs will take place at a given location in time and space

Also please note that once the nuclear processes begin, power densities in LENR-active 'patches' can go *even higher* for brief periods of time until nearby nanostructures are destroyed by violent 'flash' heating and LENRs temporarily cease in a given 'patch' (all of this occurs on the order of <1 to 300 nanoseconds)

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High local electric fields trigger condensed matter LENRs

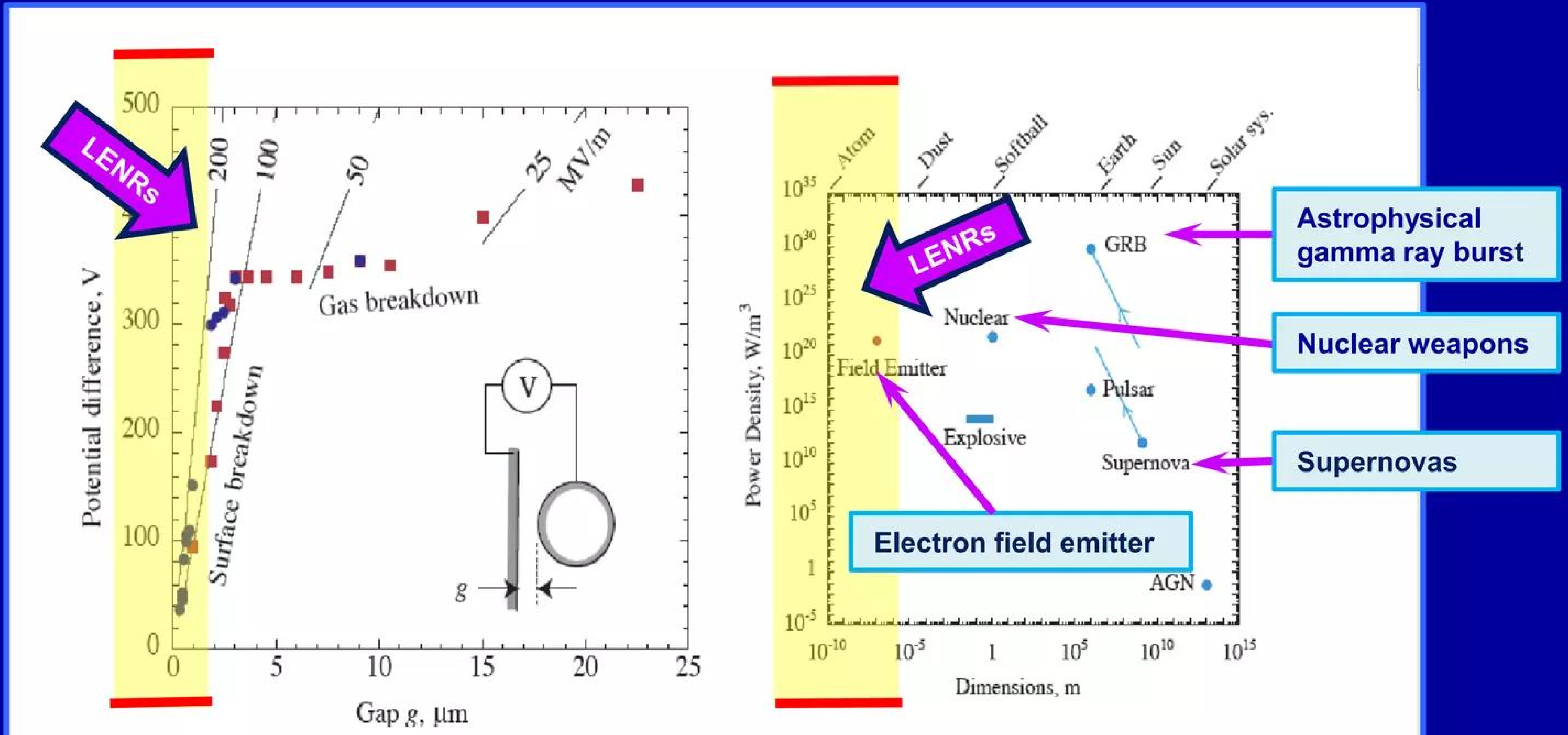
LENR aikido only requires modest macroscopic temperatures and tiny devices

Aikido physics on device surfaces enables nuclear-strength, *μ*-scale local E-fields

Local micron-scale power densities can be enormous during brief 'lifetime' of an LENR-active 'patch'

They can *exceed* huge power densities reached during electrical breakdown *a la* Seidman

Adapted by L. Larsen after Seidman & Norem (2005)



Lattice modification of original chart: yellow-shaded regions 'capped' by red-colored bars are approx. regions of parameter space where LENRs may occur in condensed matter systems IF all of the necessary conditions met (please refer back to earlier Slides)

Source: Fig. 2, pp. #3, Seidman & Norem 2005 proposal, "Experimental study of high field limits of RF cavities"

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High local electric fields trigger condensed matter LENRs

LENR aikido only requires modest macroscopic temperatures and tiny devices

Aikido physics on device surfaces enables nuclear-strength, *μ*-scale local E-fields

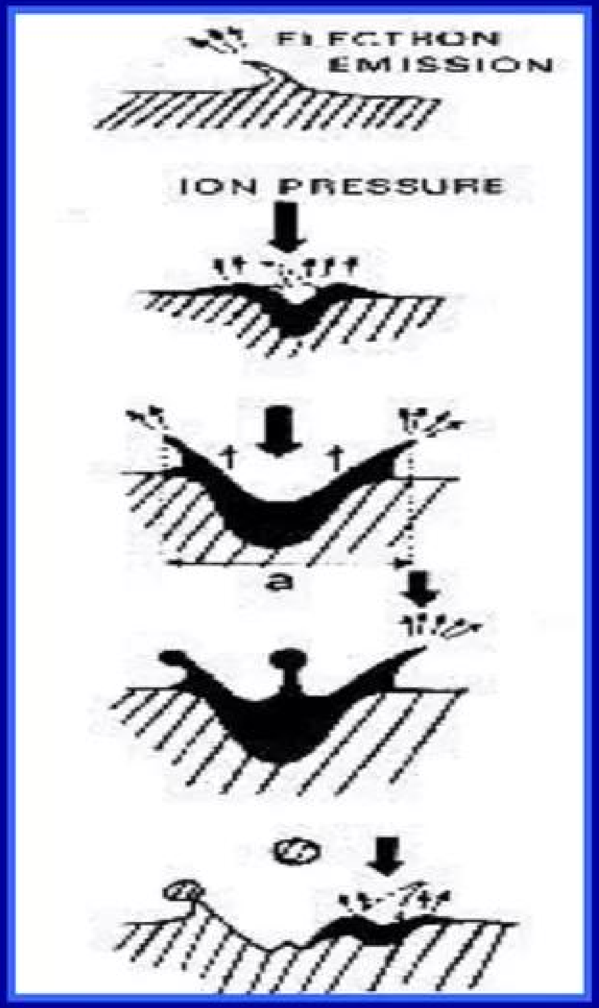
Seidman: " … highest power density commonly found in Nature"

"We think we have developed a model of breakdown that explains the phenomenon in almost all environments ….The model strongly argues that breakdown events are the result of fragments or clusters breaking off of the surface and rapidly being ionized in the electron beams from the field emitter. Within the active volume, the power involved in these beams is comparable to nuclear weapons. This model is also generally in agreement with the experience with APFIM samples at the high fields used. Tiny APFIM samples operate at fields about 5 times higher than the local E field limit we postulate, but they also frequently fail, however there has been no systematic study of these failure modes." [LENRs ??????]

"Combining these two ideas, however, one can conclude that: 1) this mechanism produces perhaps the highest power density commonly found in nature, and, 2) it is accessible to anyone with a wall switch or an electric light, and is used many times a day by everyone."

"While there has been extensive study of the time development of breakdown events from the first small local ionization to complete breakdown of a cavity, the trigger for breakdown, and how it was related to the metallurgy of surfaces has received very little attention until now. Our model predicts that the production of clusters and fragments is an essential component of breakdown. This is consistent with experience in Atom Probe Tomography, however there is almost no systematic data on sample failures under the high field environment used in data taking. Our previous work has been published in three refereed papers and many conference papers."

Pulsed Laser Atom Probe Microscope at NWU
Source: Fig. 7, pp. #9, Seidman & Norem proposal (2005)



Breakdown of surface
Figure courtesy of B. Jüttner, Berlin

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High local electric fields trigger condensed matter LENRs

LENR aikido only requires modest macroscopic temperatures and tiny devices

Peak power densities at sites could briefly be > ~3.6 x 10^{19} times that of the solar core

Simply calculated comparison of LENR 'patch' power densities vs. those thought to occur in Sun's core --- LENRs are amazingly high:

- ✓ Stromgrew (1965) calculated that peak fusion power density in Sun's core is $E_{(J)}$ = 276.5 Joules/sec·m^3 (2.765 x 10^2) - in earlier slide
- ✓ Seidman & Norem (2005) stated they believed that power densities in small sites on surfaces where collective electron field emission and electrical breakdown are occurring are = 1.0 x 10^{21} Watts/sec·m^3
- ✓ While we might safely presume that peak power density in an LENR-active patch could likely be *higher* than that Seidman & Norem's number, let's conservatively assume it's just the very same value for total LENR energy releases that occur during a given surface site's brief effective working 'lifetime' before it 'dies' and then cools-off
- ✓ Thus, according to formula shown above to the upper right, these assumptions would suggest that peak local power density from an LENR-active patch might be as high as $E_{(J)}$ = 1.0 x 10^{21} Joules/sec·m^3
- ✓ Dividing 1.0 x 10^{21} (LENRs) by 2.765 x 10^2 (Sun's core) we calculate LENRs' relative power density = ~3.6 x 10^{19} times the solar core's

Energy E in joules (J) is equal to the power P in Watts (W), times the time period t in seconds (s):

$$E_{(J)} = P_{(W)} \times t_{(s)}$$

Comments re technological issues:

- ✓ One could quibble with details in these simplistic estimates; however, conclusion of this calculation is that LENR-active sites briefly have energy power densities that can be substantially higher than the Sun's inner core
- ✓ This comparison suggests that LENRs could well have excellent potential as a new green energy source, provided that methods are found to fabricate high area-densities of LENR-active sites and that they can be reliably triggered and their rates fully-controlled

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Widom-Larsen theory explains condensed matter LENRs

Collective electroweak neutron production & capture, and nuclear decays

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

Collective effects + input energy = aikido:

$Energy_{E\text{-}field} \rightarrow e^{-*} + p^{+} \rightarrow n + \nu_e$ [chemical cells]

$Energy_{B\text{-}field} \rightarrow e^{-} + p^{+} \rightarrow lepton + X$ [solar flares]

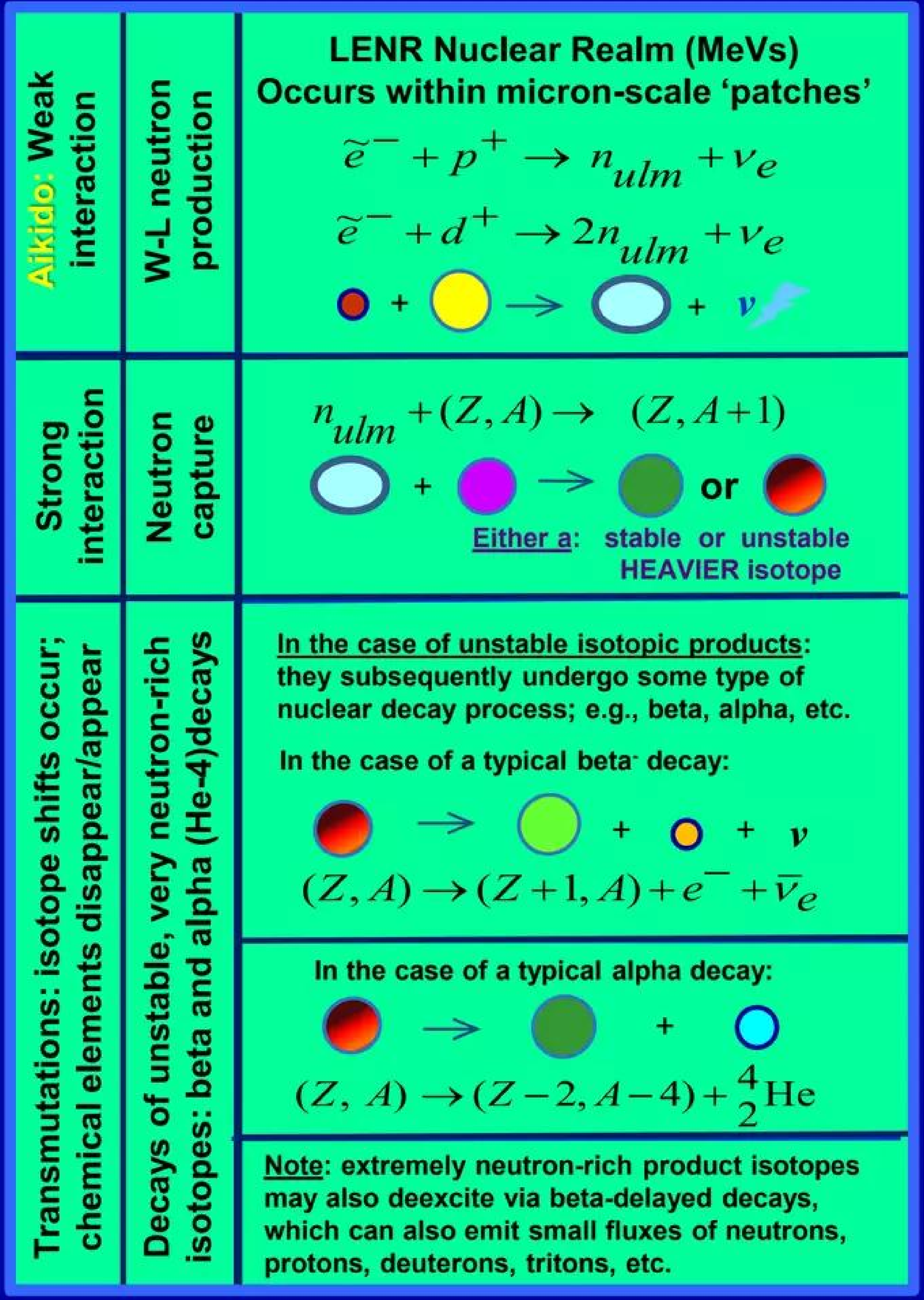
Collective electroweak production of neutrons in condensed matter and large-scale magnetic regimes

Afterwards neutrons capture on 'targets':

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

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

Mainly β^- decays of neutron-rich isotopic products



Aikido: Weak interaction	**W-L neutron production**	**LENR Nuclear Realm (MeVs)** **Occurs within micron-scale 'patches'** $\tilde{e}^- + p^+ \rightarrow n_{ulm} + \nu_e$ $\tilde{e}^- + d^+ \rightarrow 2n_{ulm} + \nu_e$ ● + ● → ⬭ + ν
Strong interaction	**Neutron capture**	$n_{ulm} + (Z, A) \rightarrow (Z, A+1)$ ⬭ + ● → ● or ● Either a: stable or unstable HEAVIER isotope
Transmutations: isotope shifts occur; chemical elements disappear/appear	**Decays of unstable, very neutron-rich isotopes: beta and alpha (He-4)decays**	In the case of unstable isotopic products: they subsequently undergo some type of nuclear decay process; e.g., beta, alpha, etc. In the case of a typical beta$^-$ decay: ● → ● + ● + ν $(Z, A) \rightarrow (Z+1, A) + e^- + \bar{\nu}_e$ In the case of a typical alpha decay: ● → ● + ○ $(Z, A) \rightarrow (Z-2, A-4) + {}^{4}_{2}\mathrm{He}$ Note: extremely neutron-rich product isotopes may also deexcite via beta-delayed decays, which can also emit small fluxes of neutrons, protons, deuterons, tritons, etc.

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Widom-Larsen theory explains condensed matter LENRs

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

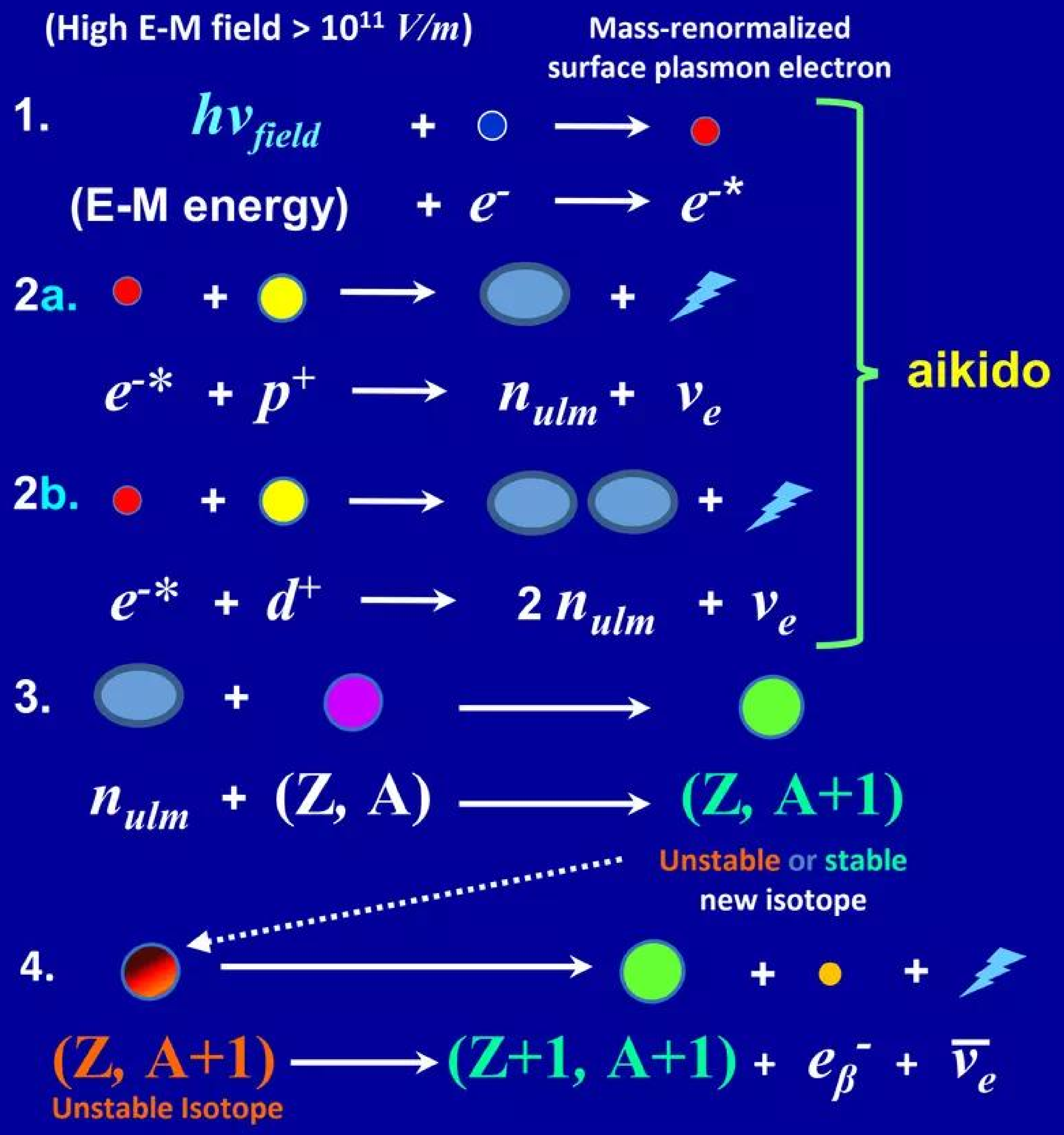
Steps 1. thru 3. are very fast: can complete in 2 to 300 nanoseconds

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

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

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

(High E-M field > 10^{11} V/m)



1. $h\nu_{field}$ (E-M energy) $+ e^- \longrightarrow e^{-*}$

2a. $e^{-*} + p^+ \longrightarrow n_{ulm} + \nu_e$

2b. $e^{-*} + d^+ \longrightarrow 2\, n_{ulm} + \nu_e$

3. $n_{ulm} + (Z, A) \longrightarrow (Z, A+1)$

4. $(Z, A+1) \longrightarrow (Z+1, A+1) + e_\beta^- + \bar{\nu}_e$

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

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Widom-Larsen theory explains condensed matter LENRs

Many-body collective & quantum effects are crucial to achieving aikido-state

Table shows key attributes of W-L many-body LENR-active surface 'patches'

	Type of particle in LENR-active patch	Are particles in patch charged?	Dimensionality	Do particles collectively oscillate?	Are particles Q-M entangled?	Comments
Widom-Larsen surface patch Sizes vary randomly - diameters can range from several nm to perhaps up to ~100 microns	**Surface plasmon electrons** (fermions) Decidedly many-body	Yes, -	~2-D to 3-D somewhat reduced	Yes	Yes Q-M wave functions are very delocalized within a patch	Very high nuclear-strength electric fields > 2 x 10^{11} V/m present within an energized patch; this increases local SP electron masses, allowing some of them to directly react with protons in e + p → n + ν
	Surface protons (hydrogen) (fermions) Decidedly many-body	Yes, +	~2-D to 3-D somewhat reduced	Yes	Yes Q-M wave functions are very delocalized within a patch	Very high nuclear-strength electric fields > 2 x 10^{11} V/m present within an energized patch thanks to E-M coupling and breakdown of the Born-Oppenheimer approximation
Substrate material	Mostly neutral atoms except for interstitial absorbed hydrogenous ions that occupy material-specific sites in substrate bulk lattice	No charge-neutral for the most part	Essentially 3-D i.e., bulk material	No	No	When protons are 'loaded' into a hydride-forming lattice, they occupy specific interstitial sites. After site occupancies > ~0.80 , protons start 'leaking' back onto surface, forming collectively oscillating, Q-M entangled, ~2-D monolayer 'pools' of protons that E-M couple locally to surface plasmon electrons

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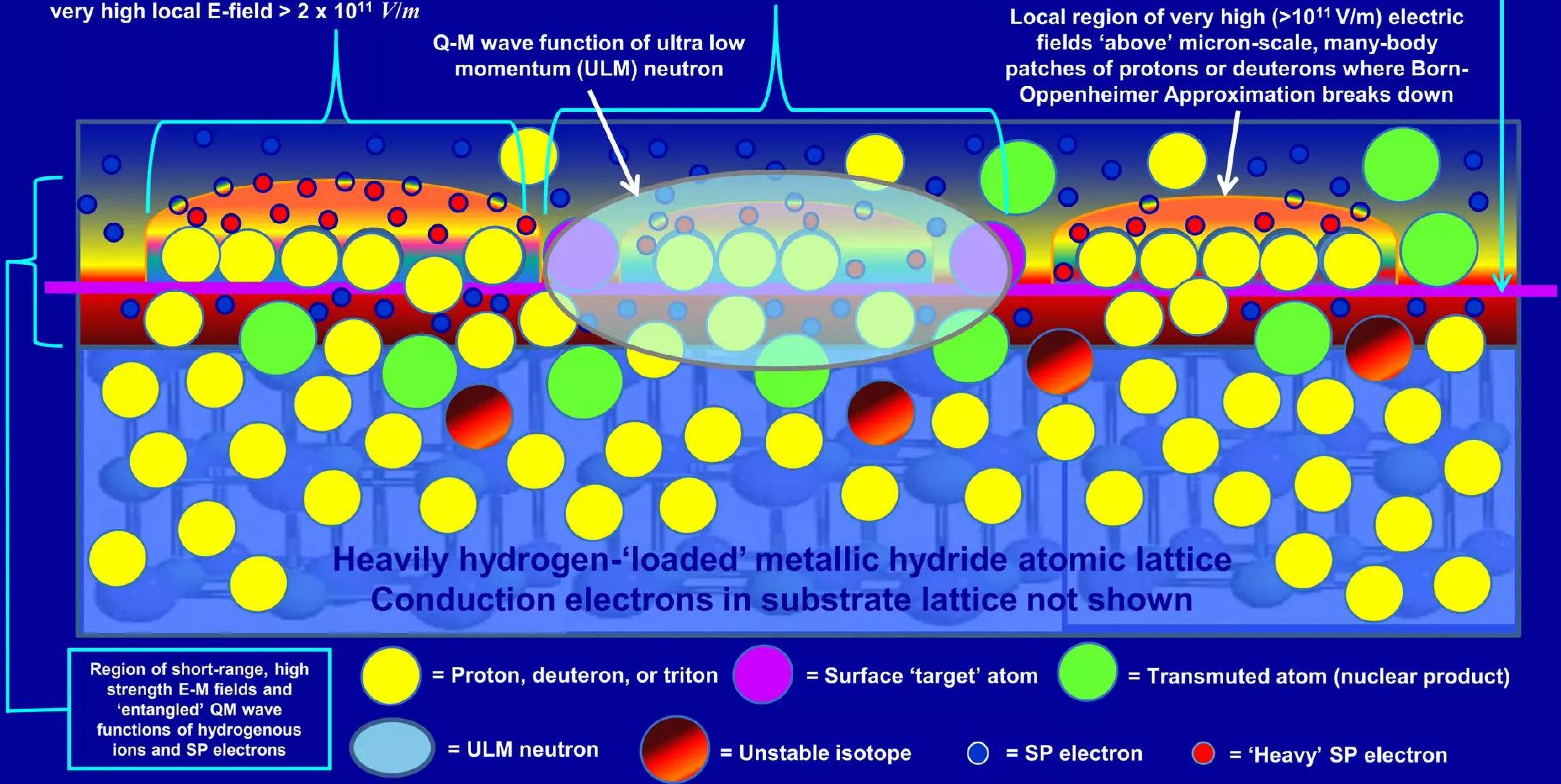
Widom-Larsen theory explains condensed matter LENRs

LENRs occur in micron-scale regions on surfaces: the haunts of aikido



Collectively oscillating many-body 'patch' of protons or deuterons with nearby 'heavy' mass-renormalized SP electrons 'bathed' in very high local E-field > 2 x 10^{11} *V/m*

A proton has just reacted with a SP electron, creating a 'ghostly' ULM neutron via $e^* + p$ weak interaction; QM wavelength same 'size' as 'patch'

Surface of metallic hydride substrate

Q-M wave function of ultra low momentum (ULM) neutron

Local region of very high (>10^{11} V/m) electric fields 'above' micron-scale, many-body patches of protons or deuterons where Born-Oppenheimer Approximation breaks down

Heavily hydrogen-'loaded' metallic hydride atomic lattice
Conduction electrons in substrate lattice not shown

Region of short-range, high strength E-M fields and 'entangled' QM wave functions of hydrogenous ions and SP electrons

🟡 **= Proton, deuteron, or triton**

🟣 **= Surface 'target' atom**

🟢 **= Transmuted atom (nuclear product)**

⬭ **= ULM neutron**

● **= Unstable isotope**

○ **= SP electron**

🔴 **= 'Heavy' SP electron**

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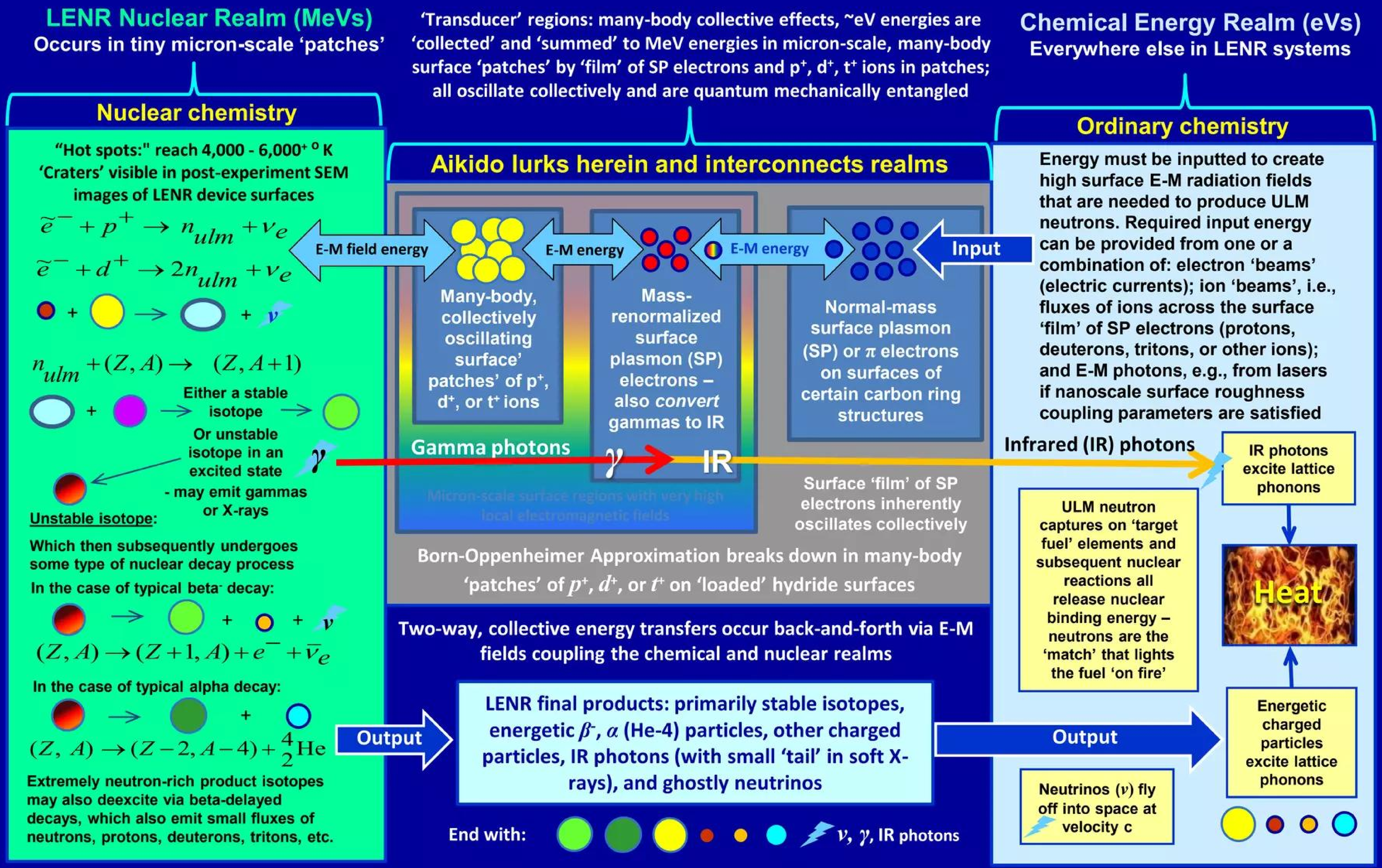
Widom-Larsen theory explains condensed matter LENRs



LENR Nuclear Realm (MeVs)
Occurs in tiny micron-scale 'patches'

'Transducer' regions: many-body collective effects, ~eV energies are 'collected' and 'summed' to MeV energies in micron-scale, many-body surface 'patches' by 'film' of SP electrons and p⁺, d⁺, t⁺ ions in patches; all oscillate collectively and are quantum mechanically entangled

Chemical Energy Realm (eVs)
Everywhere else in LENR systems

Nuclear chemistry

"Hot spots:" reach 4,000 - 6,000⁺ ᴼ K
'Craters' visible in post-experiment SEM images of LENR device surfaces

$$\tilde{e}^- + p^+ \rightarrow n_{ulm} + \nu_e$$

$$\tilde{e}^- + d^+ \rightarrow 2n_{ulm} + \nu_e$$

$$n_{ulm} + (Z,A) \rightarrow (Z,A+1)$$

Either a stable isotope

Or unstable isotope in an excited state - may emit gammas or X-rays

Unstable isotope:

Which then subsequently undergoes some type of nuclear decay process

In the case of typical beta⁻ decay:

$$(Z,A) \rightarrow (Z+1,A) + e^- + \bar{\nu}_e$$

In the case of typical alpha decay:

$$(Z,\ A) \rightarrow (Z-2, A-4) + {}^{4}_{2}\mathrm{He}$$

Extremely neutron-rich product isotopes may also deexcite via beta-delayed decays, which also emit small fluxes of neutrons, protons, deuterons, tritons, etc.

Aikido lurks herein and interconnects realms

E-M field energy

E-M energy

E-M energy

Input

Many-body, collectively oscillating surface' patches' of p⁺, d⁺, or t⁺ ions

Mass-renormalized surface plasmon (SP) electrons – also *convert* gammas to IR

Normal-mass surface plasmon (SP) or π electrons on surfaces of certain carbon ring structures

Gamma photons

γ IR

Micron-scale surface regions with very high local electromagnetic fields

Surface 'film' of SP electrons inherently oscillates collectively

Born-Oppenheimer Approximation breaks down in many-body 'patches' of p^+, d^+, or t^+ on 'loaded' hydride surfaces

Two-way, collective energy transfers occur back-and-forth via E-M fields coupling the chemical and nuclear realms

Ordinary chemistry

Energy must be inputted to create high surface E-M radiation fields that are needed to produce ULM neutrons. Required input energy can be provided from one or a combination of: electron 'beams' (electric currents); ion 'beams', i.e., fluxes of ions across the surface 'film' of SP electrons (protons, deuterons, tritons, or other ions); and E-M photons, e.g., from lasers if nanoscale surface roughness coupling parameters are satisfied

Infrared (IR) photons

IR photons excite lattice phonons

ULM neutron captures on 'target fuel' elements and subsequent nuclear reactions all release nuclear binding energy – neutrons are the 'match' that lights the fuel 'on fire'

Heat

Energetic charged particles excite lattice phonons

Output

Output

LENR final products: primarily stable isotopes, energetic β^-, α (He-4) particles, other charged particles, IR photons (with small 'tail' in soft X-rays), and ghostly neutrinos

Neutrinos (ν) fly off into space at velocity c

End with: ν, γ, IR photons

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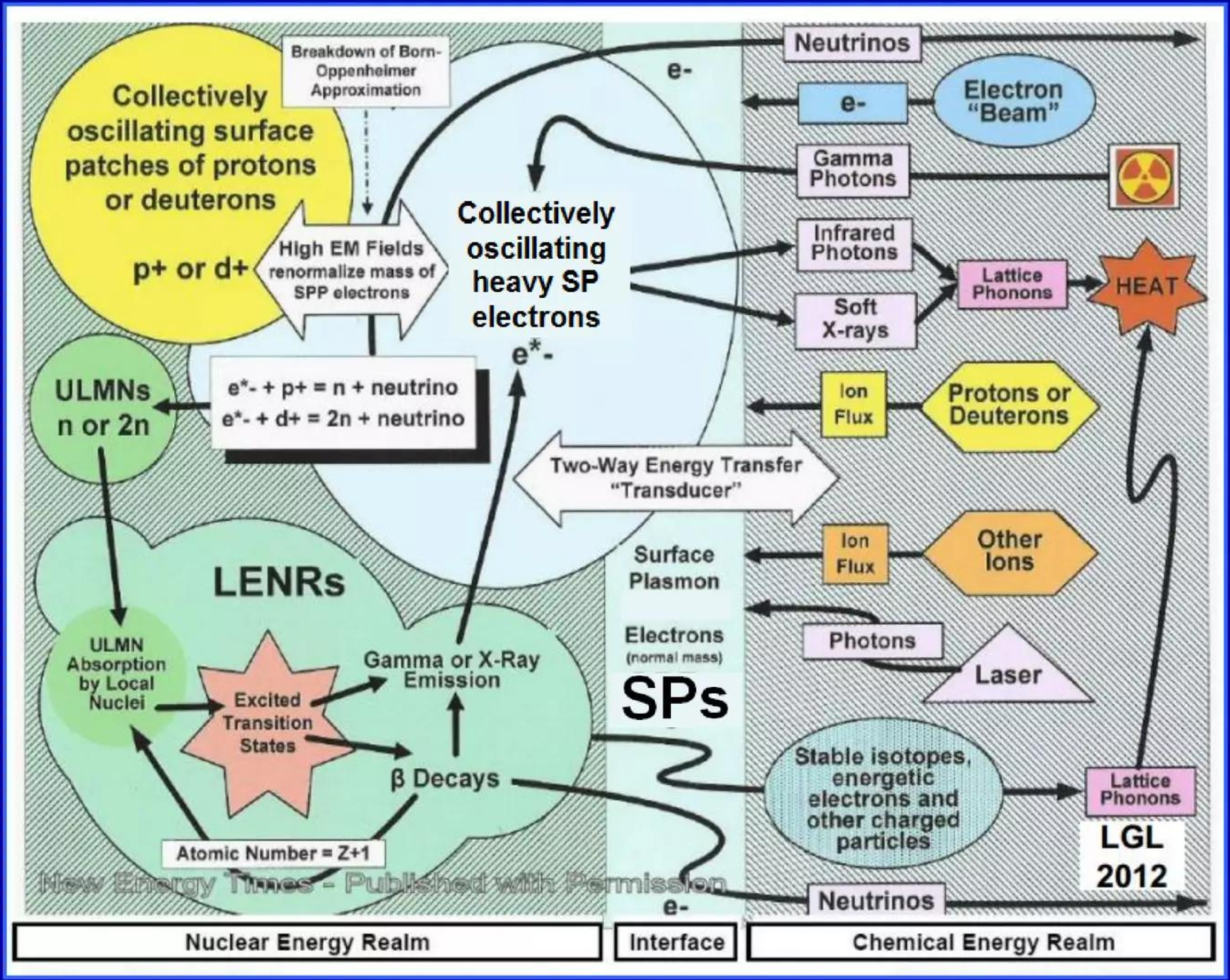
Widom-Larsen theory explains condensed matter LENRs

Collective many-body physics and SP electrons interface between realms



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Widom-Larsen theory explains condensed matter LENRs

No 'free lunch': many-body collective neutron production needs input energy

- ✓ **Input energy is required: to create non-equilibrium conditions that enable nuclear-strength local E-fields which produce populations of heavy-mass e^{-*} electrons that react with many-body surface 'patches' of p^+, d^+, or t^+ to produce neutrons via $e^{-*} + p^+ \rightarrow 1\ n$ or $e^{-*} + d^+ \rightarrow 2\ n$, etc. (cost = 0.78 MeV/neutron for H; 0.39 for D; 0.26 for T); includes (can be combined):**
  - **Electrical currents - i.e., an electron 'beam' of one sort or another can serve as input source**
  - **Ion currents - across the interface on which SP electrons reside (i.e., an ion 'beam' that can be comprised of protons, deuterons, tritons, and/or other types of charged ions); one method used to input energy is ion flux caused by imposing a pressure gradient (Iwamura *et al.* 2002)**
  - **Incoherent and coherent E-M photon fluxes - can be incoherent E-M radiation found in resonant electromagnetic cavities; with proper coupling, SP electrons can also be directly energized with coherent laser 'beams' emitting photons at appropriate resonant wavelengths**
  - **Organized magnetic fields with cylindrical geometries - mainly at very high electron currents; includes organized, non-ideal so-called 'dusty' plasmas --- scales way-up to stellar flux tubes**
- ✓ **Key feature of complex multi-step LENR transmutation networks: large numbers of viable network pathways can release more net nuclear binding energy that arises from a combination of neutron captures (with direct conversion of resulting prompt and delayed gammas into IR per W-L theory) and nuclear decays (e.g., α, β, etc.) vs. input energy that is required to produce total numbers of neutrons required for network pathway(s) to operate**

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Widom-Larsen theory explains condensed matter LENRs

Basic requirements for successfully triggering LENRs include the following:

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

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

- ✓ Born-Oppenheimer approximation breaks down in tiny surface ‘patches’ of contiguous collections of collectively oscillating p^+, d^+, and/or t^+ ions; enables E-M coupling between nearby SP or π electrons and hydrogen ions at these locations; creates nuclear-strength local electric fields > 2 x 10^{11} V/m; effective masses of electrons in that field are then increased to a multiple of an electron at rest ($e \rightarrow e^*$) - determined by required ~simultaneous energy input(s)

- ✓ System must be subjected to external non-equilibrium fluxes of charged particles or E-M photons that are able to transfer input energy directly to many-body SP or π electron ‘surface films.’ Examples of such external energy sources include (they may be used in combination): electric currents (i.e., electron ‘beams’); E-M photons (e.g., emitted from lasers, IR-resonant E-M cavity walls, etc.); pressure gradients of p^+, d^+, and/or t^+ ions imposed across ‘surfaces’; currents of other ions crossing the ‘SP electron surface’ in either direction (ion ‘beams’); etc. Such sources can provide additional input energy required to surpass certain minimum H-isotope-specific electron-mass thresholds that allow production of ULM neutron fluxes via $e^* + p^+$, $e^* + d^+$, or $e^* + t^+$ weak interactions

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

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Widom-Larsen theory explains condensed matter LENRs

See Q-M entangled many-body 'patches' of protons (H) on Pd-hydride surface

- ✓ **"Hydrogen absorption and diffusion on Pd(111)"**
  T. Mitsui *et al*.
  ***Surface Science* 540 pp. 5 - 11 (2003)**
  http://144.206.159.178/ft/976/183940/4699801.pdf

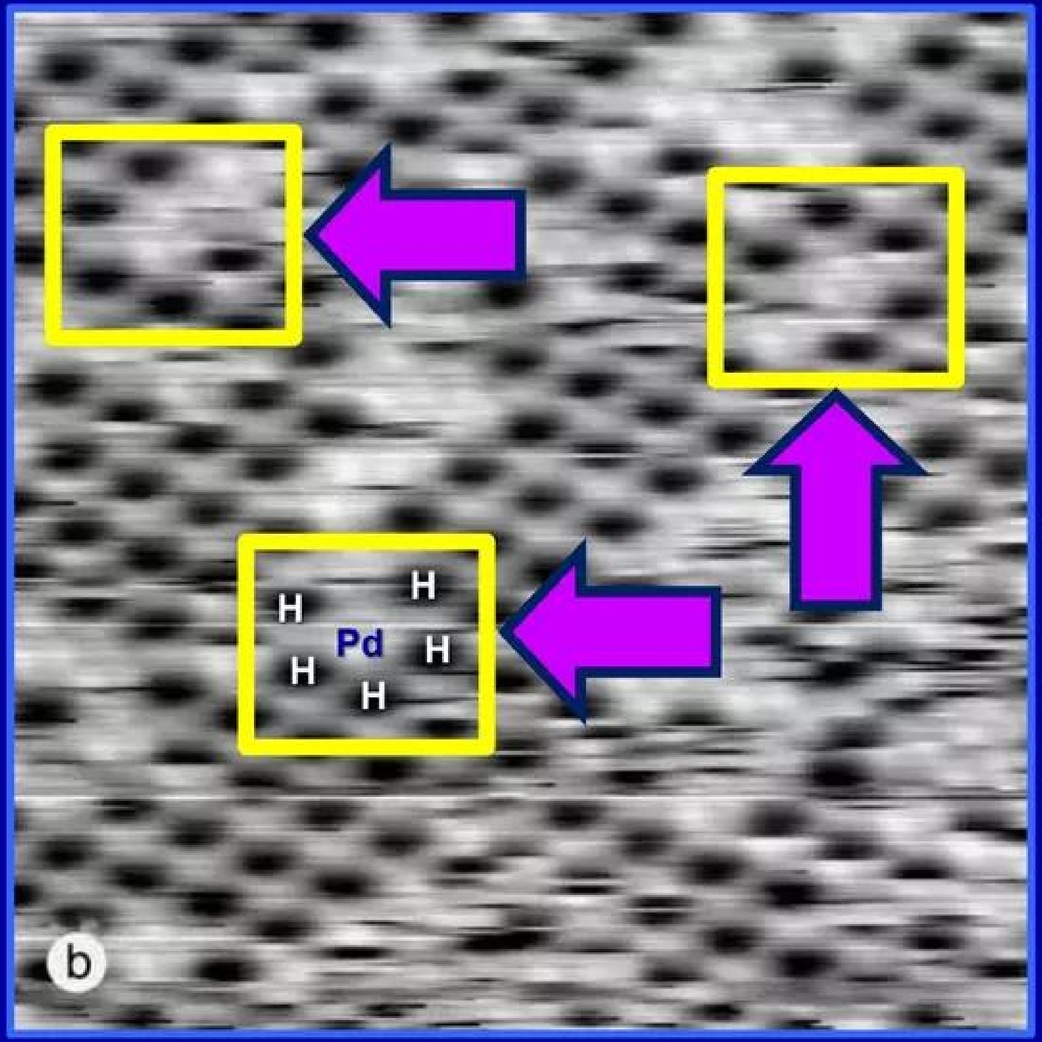
  Abstract: "The adsorption, diffusion and ordering of hydrogen on Pd(111) was studied by scanning tunneling microscopy in the temperature range of 37 - 90 K. At low coverage isolated hydrogen atoms were observed. They formed √3 x √3-1H islands as the coverage increased. Above 1/3 monolayer (ML) coverage areas of a new phase with √3 x √3 -2H structure were formed, with both structures coexisting between 1/3 and 2/3 ML. Finally a 1 x 1 structure was formed after high exposures of hydrogen above 50 K, with a coverage close to 1 ML. Atomically resolved images reveal that H binds to fcc hollow sites."

  Quoting an excerpt therefrom: "… to our knowledge, an STM study of hydrogen adsorption on a closed packed (111) metal surface has [previously] not been reported."

- ✓ **Lattice comment: image at right shows many-body 'patches' of protons on a surface. Visual inspection of STM image in adapted version of Fig. 1 reveals that under Mitsui *et al.'s* experimental conditions, PdHx ratios at many surface sites would appear to be comfortably above the minimal critical value of H/Pd > 0.80 necessary for LENR triggering. In fact, PdHx H/Pd ratios at some sites can apparently range perhaps as high as x = 5.0 (again, see Figure 1. to right)**

  Therefore, similarly high PdHx ratios would seem to be plausible in the case of high % surface coverage of hydrogen atoms (protons) on fully 'loaded' Pd(111) surfaces at room temperature of 273 K and beyond. Thus, high PdHx ratios could reasonably be expected to occur within the many-body, entangled hydrogenous 'patches' conjectured in the Widom-Larsen theory of LENRs

STM image of H on Pd(111) adapted from: Fig. 1 in Mitsui *et al*., *Surface Science* (2003)



Quoting from Fig. 1 caption in paper: "Fig. 1. (a) 10 x 10 nm image of the Pd(111) surface after a short exposure to H_2 gas. Isolated H atoms are the dark spots, corresponding to 15 pm depressions. The atoms diffuse thermally and also by the influence of the tip, forming the dark streaks seen in the image. (b) At a coverage of 0.2 ML islands with √3 x √3 *R*30° structure are formed. The H atoms are now stable and do not diffuse. The influence of the tip is now negligible. The Pd atoms are the bright spots between the H islands, with a corrugation of ~2 pm. The H site, at the center of an upward pointing triangle of Pd atoms is the fcc hollow. Tunneling conditions: ~45 mV tip bias and 11 nA current."

Widom-Larsen theory explains condensed matter LENRs

LENRs produce distinctive surface features that can be seen in SEM images

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

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

- ✓ **While ULM neutron production and local capture, gamma conversion to IR by heavy electrons, and subsequent nuclear decays are occurring, these tiny 'patches' temporarily become 'hot spots.' Their temperatures may briefly reach 4,000 - 6,000^{o} K or perhaps even higher. That value is roughly as high as the 'surface' temperature of the Sun and hot enough to melt and/or even flash-boil essentially all metals and alloys, including Tungsten (b.p. 5,666^{o} C). For a brief time, a tiny dense 'ball' of very hot, 'nanodusty' plasma is created. Such intense local heating events can produce various types of distinctive explosive melting features and/or comparatively deep 'craters' that are often observed in post-experiment SEM images of LENR device surfaces; for example, please see Zhang & Dash's SEM-EDX image of such 'craters' on Slide #54 herein**

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Widom-Larsen theory explains condensed matter LENRs

LENR-active surfaces have many different, dynamically interacting processes

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

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

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

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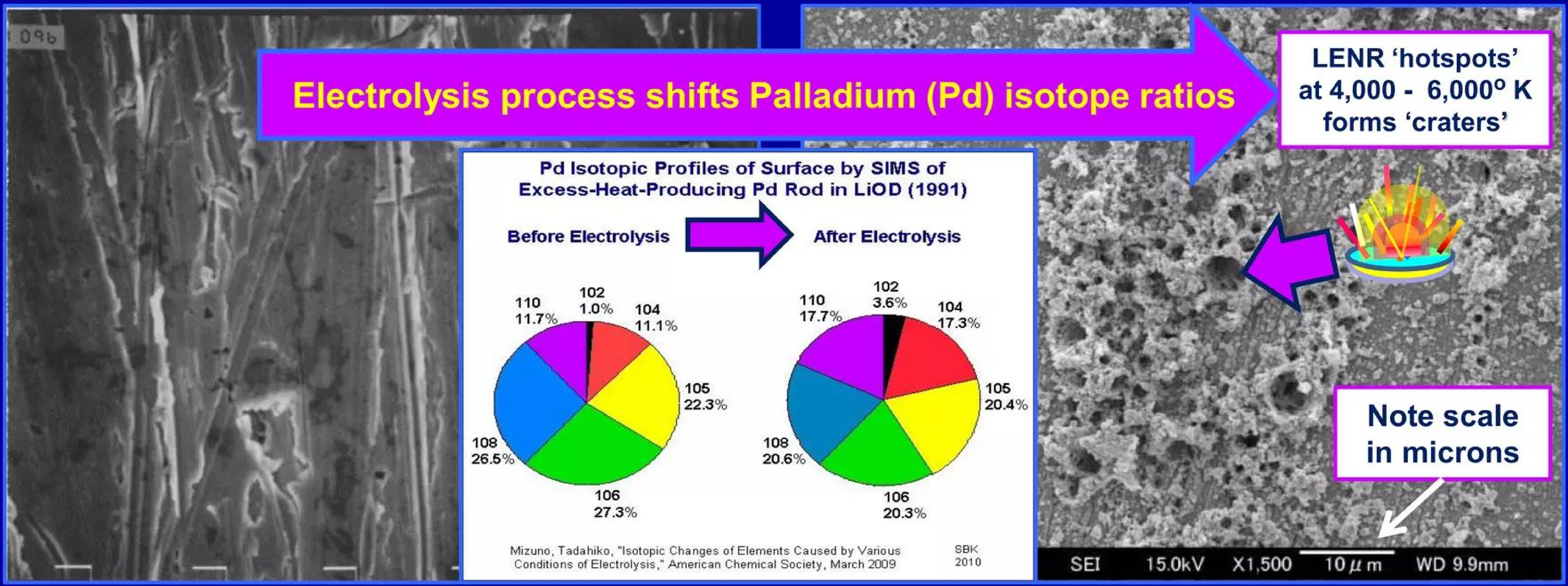
LENR products are observed on device surfaces

Researchers see post-experiment remains of LENR-active 'hotspot crater' sites

Mizuno *et al.* reported on new experiments with chemical cells at ICCF-17 (2012)

Before: relatively smooth surface **After: rugged terrain on micron-scales**



Electrolysis process shifts Palladium (Pd) isotope ratios

LENR 'hotspots' at 4,000 - 6,000° K forms 'craters'

Note scale in microns

Pd Isotopic Profiles of Surface by SIMS of Excess-Heat-Producing Pd Rod in LiOD (1991)

Mizuno, Tadahiko, "Isotopic Changes of Elements Caused by Various Conditions of Electrolysis," American Chemical Society, March 2009

Quoting Slide #5 caption in ICCF-17 presentation: "These photo are the Pd electrode before and after the electrolysis. Electrolysis was conducted for a long time, several day or several week. Typical current density was 20mA/cm^2. Here, you see the metal particle (100 nm or less) on the surface after electrolysis. Some of them are less than 10 nano-meter of size."

Source: 41-slide ICCF-17 conference (Aug. 12-17, 2012, Daejeon, Korea) presentation titled, "Theoretical Analysis of Chemically Assisted Nuclear Reactions (CANR) in Nanoparticles," T. Mizuno, M. Okuyama, Y. Ishikawa, and T. Oheki

Copy of slides available at: http://newenergytimes.com/v2/conferences/2012/ICCF17/ICCF-17-Mizuno-Theoretical-Analysis-Slides.pdf

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LENR products are observed on device surfaces

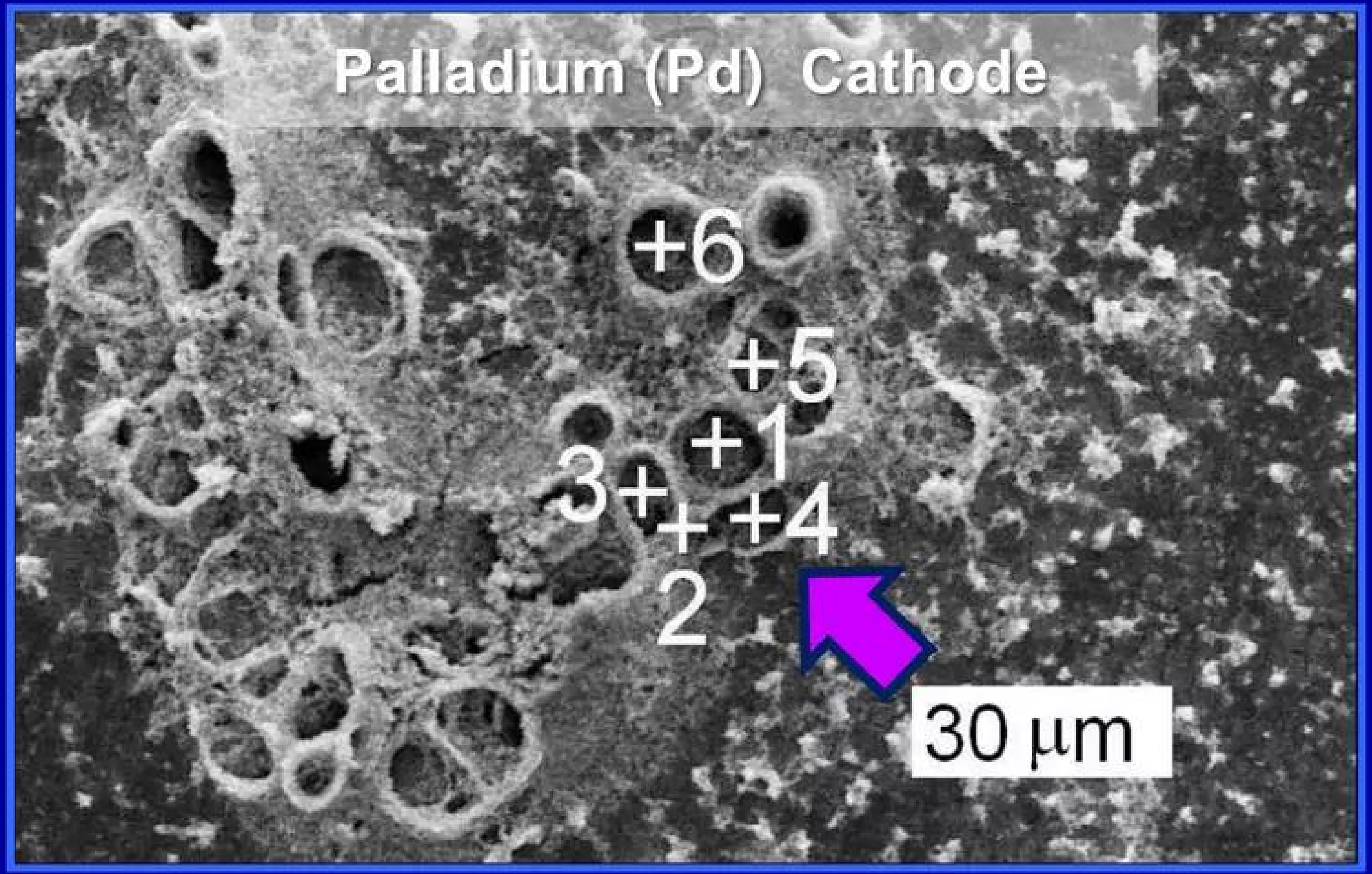
Palladium was transmuted into Silver with ULM neutron capture and β-decay

Following nuclear reactions would explain observations reported in these experiments:

neutron capture process β^- nuclear decay process

[Multiple stable Palladium isotopes] Pd + n → [unstable neutron-rich Pd isotopes] → Ag [two stable Silver isotopes]

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



Note: Pd b.p. = 2,970°C

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

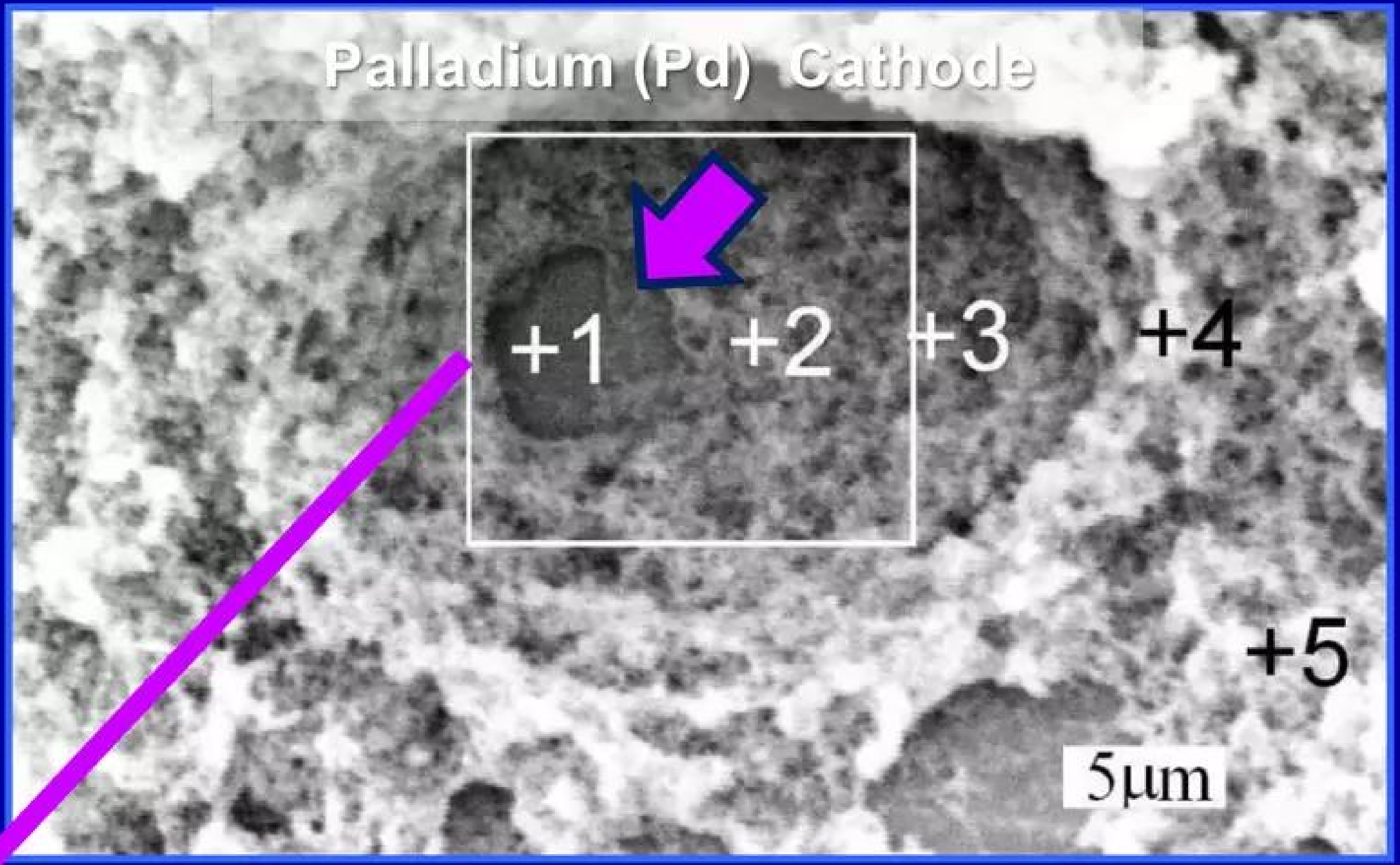


Fig. 9. SEM picture of crater at another time. SEM No.WS060607Pd-H-CC-i2-2kX

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

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

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

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

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

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LENR products are observed on device surfaces

Anomalous Nickel (Ni) was found on Palladium device surface post-experiment

Ag and Ni were not present when experiments began - chemical processes cannot create new elements

Reference:

"Excess heat reproducibility and evidence of anomalous elements after electrolysis in Pd/D_2O + H_2SO_4 electrolytic cells"

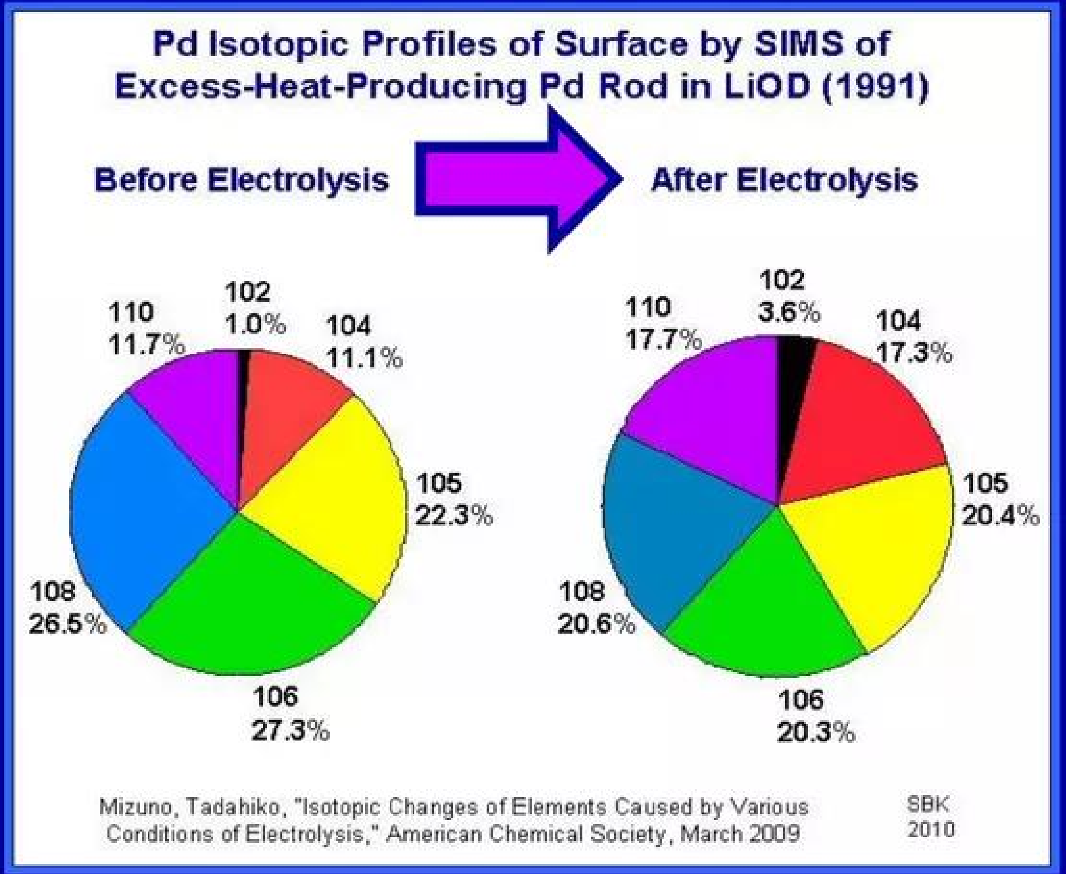
W. Zhang and J. Dash

Presented at the 13th International Conference on Condensed Matter Nuclear Science, Sochi, Russia (2007)

Free copy of above paper available at:

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

T. Mizuno & H. Kozima - ACS (March 2009):



Pd Isotopic Profiles of Surface by SIMS of Excess-Heat-Producing Pd Rod in LiOD (1991)

Mizuno, Tadahiko, "Isotopic Changes of Elements Caused by Various Conditions of Electrolysis," American Chemical Society, March 2009

SBK 2010

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

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

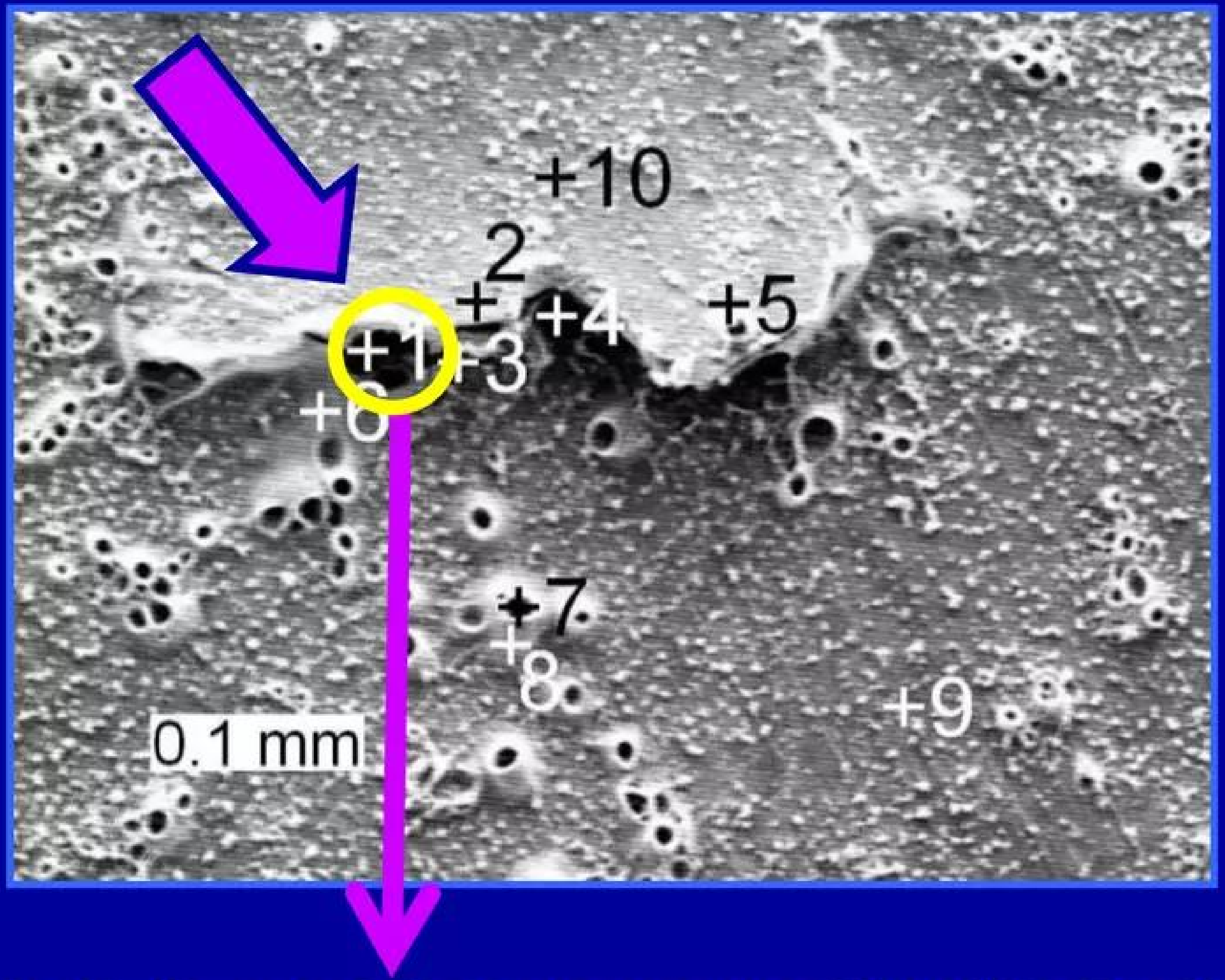
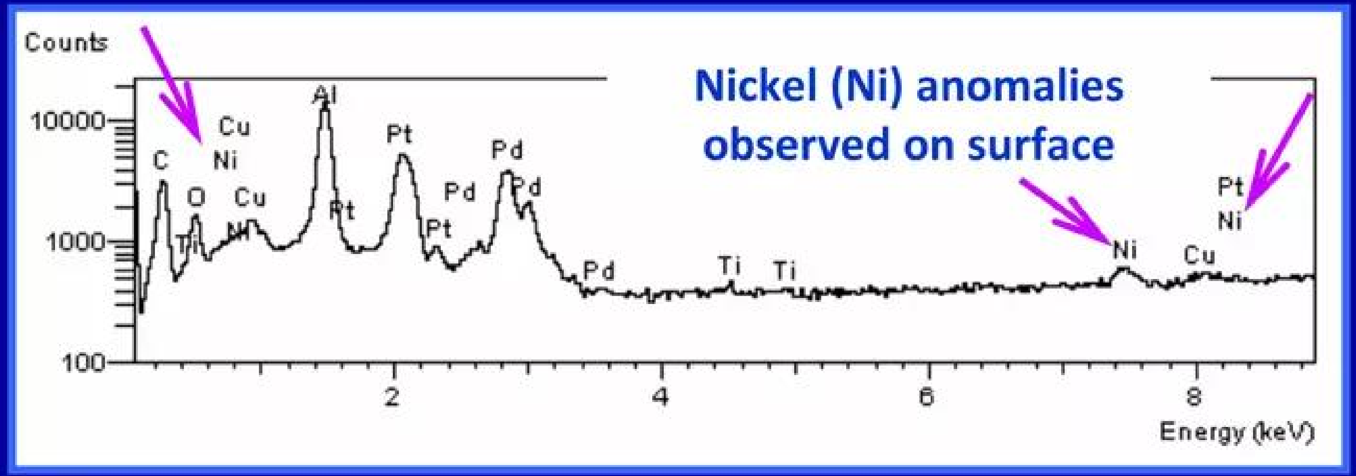


Fig. 11. Characteristic X-ray spectrum of Spot #1 in Fig. 10



Nickel (Ni) anomalies observed on surface

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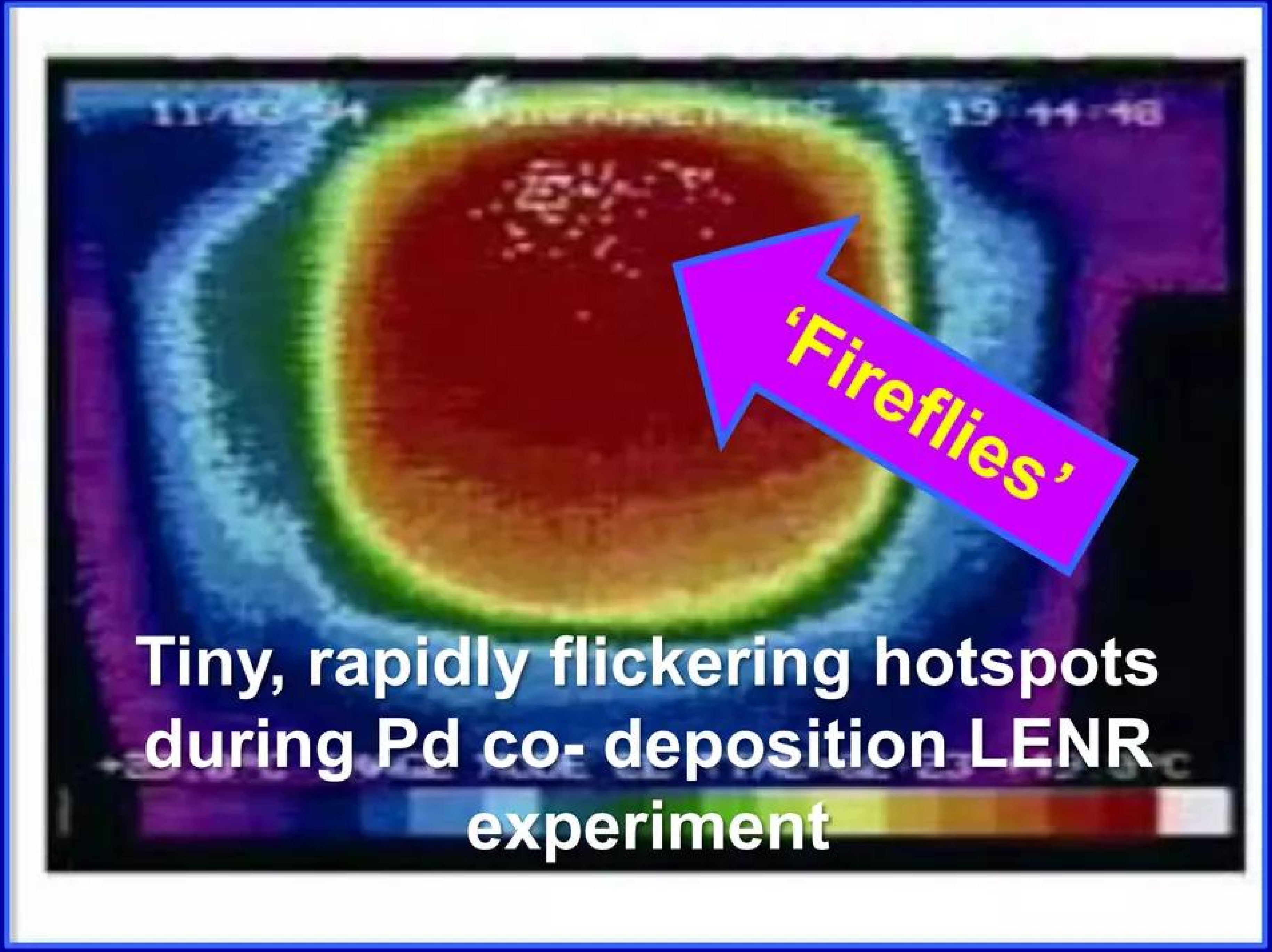
U.S. Navy imaged LENR-active cathode surface with IR

SPAWAR's high-speed camera showed 'fireflies' of nuclear hotspots in infrared



'Fireflies'

Tiny, rapidly flickering hotspots during Pd co- deposition LENR experiment

Readers are urged to view USN SPAWAR's (P. Boss *et al.*) fascinating short video clip: it is very reminiscent of high-speed 'flickering' of thousands of tiny fireflies in a dark field at night

2005 - U.S. Navy SPAWAR San Diego LENR Research Lab: Infrared Measurements
Jan 13, 2009 - 2 min - Uploaded by Steven Krivit
http://www.youtube.com/watch?v=Pb9V_qFKf2M&feature=player_embedded

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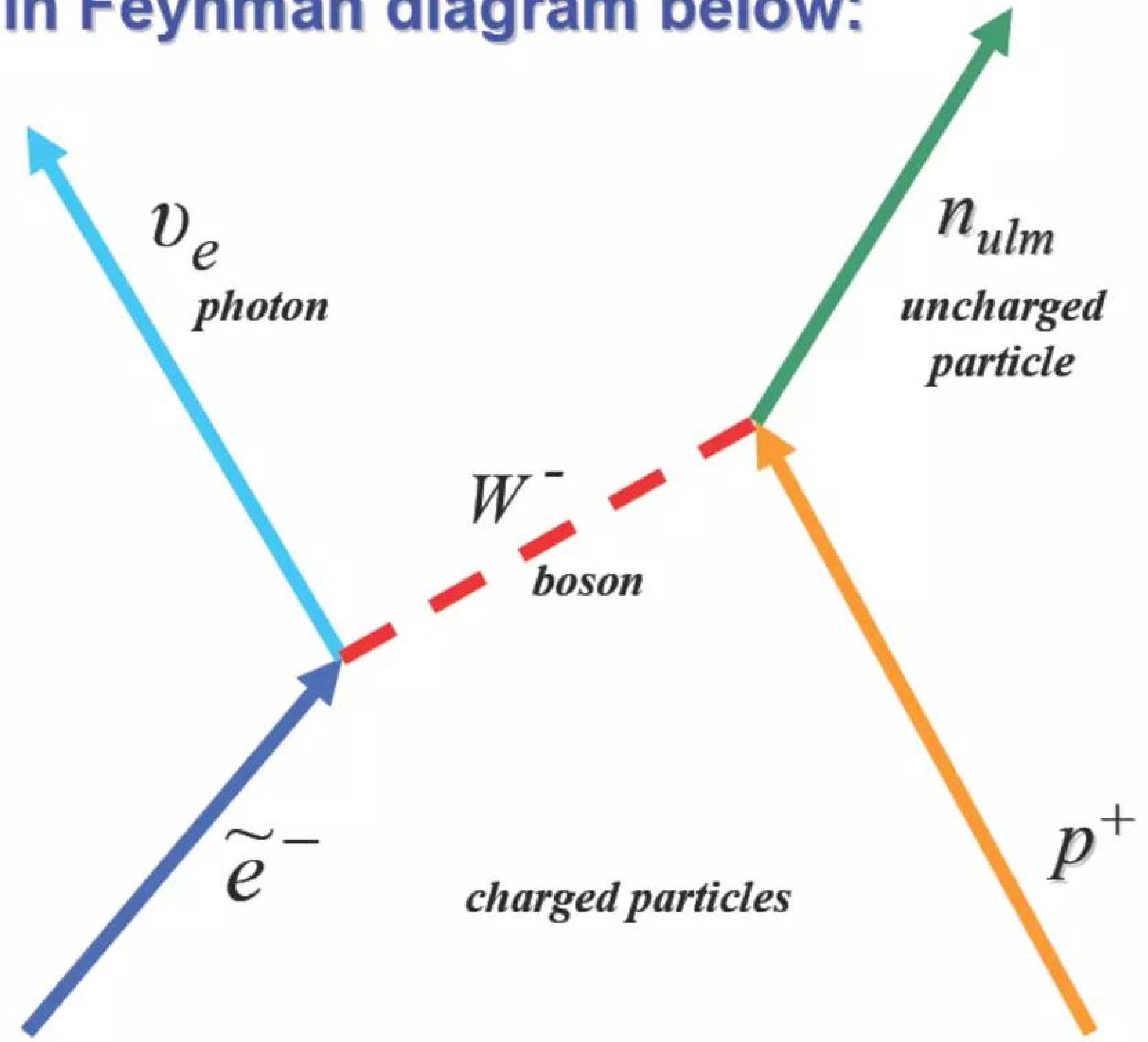
Many-body collective & quantum effects crucial to aikido

While written as two-body e^- + p^+ reaction, what happens in Nature is many-body

In LENRs, many-body collective effects also involve mutual quantum entanglement

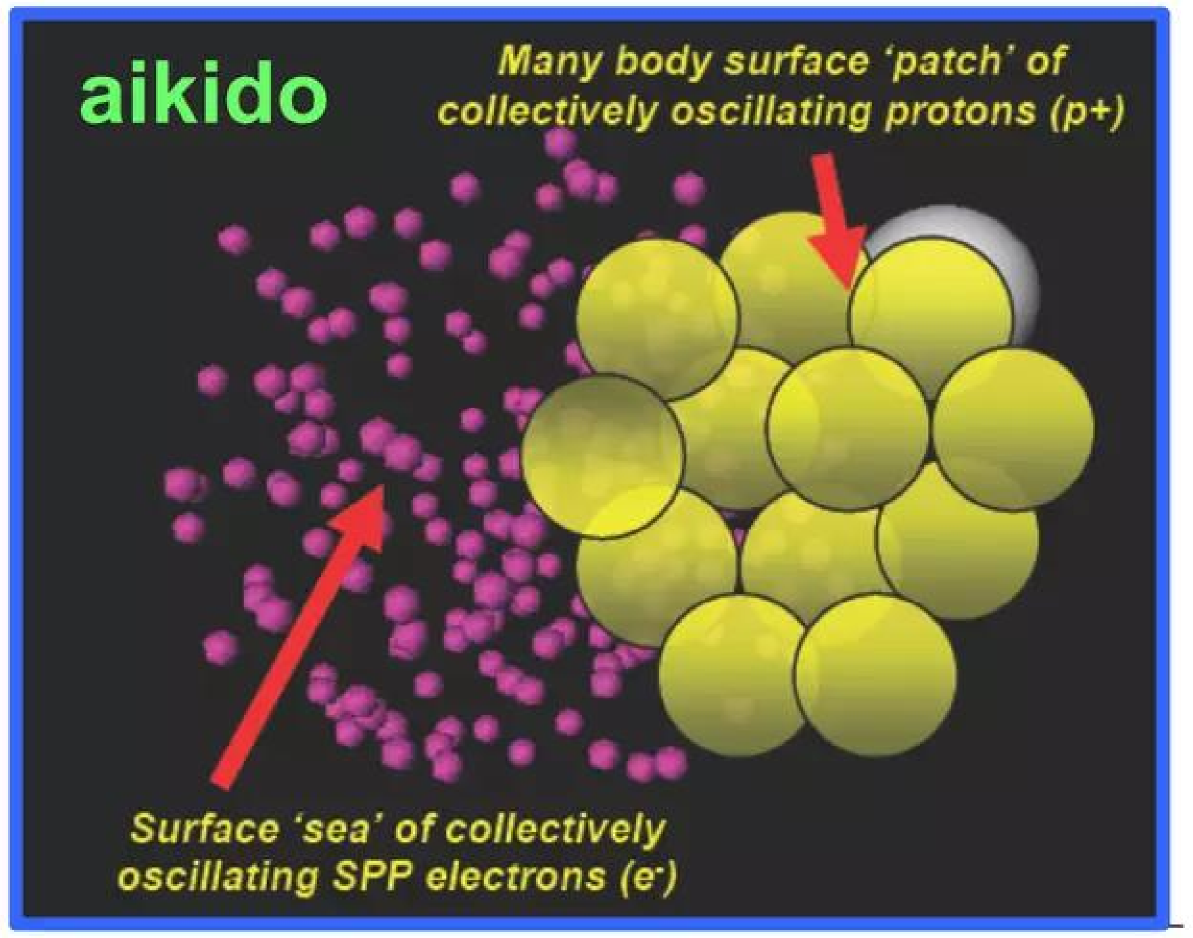
Simple two-body collision shown in Feynman diagram below:



$$\tilde{e}^- + p^+ \longrightarrow n_{ulm} + \nu_e$$

What really happens is many-body

Now add collective rearrangements from condensed matter effects. It is not just a two body collision !!!



Above is what really occurs on metallic hydride cathodes

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Stars, fission reactors, tokamaks, and thermonuclear explosions - not required

Collective many-body transport and concentration of incident electromagnetic energy

- ✓ **Under proper conditions, $e + p \rightarrow n + v_e$ (endothermic by 0.78 MeV) electroweak "neutronization" reaction (surface plasmon SP electron reacts directly with a surface proton to make a neutron and an electron neutrino) can occur at unexpectedly high rates in micron-scale, monolayer, many-body 'patches' of collectively oscillating protons or deuterons that can form spontaneously on fully 'loaded' metallic hydride surfaces (bulk hydride interstitial H sites are all occupied)**
- ✓ **These surface 'patch' sites range in size from ~2 nm to ~100 microns; they can become LENR-active when sufficient amounts of E-M input energy in the right form is transported to, and concentrated in, them by wide-area 'film' of entangled SP electrons that cover entire surface of a metallic hydride device (delocalized, entangled π electrons on the 'surfaces' of hydrogenated Carbon-based aromatic rings can serve the same function as SP electrons found on metallic hydride surfaces)**

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Stars, fission reactors, tokamaks, and thermonuclear explosions - not required

Local concentration of E-M energy causes 'patch' SP electron masses to increase

- ✓ In such coherently oscillating 'patches' of surface protons, deuterons, or tritons the Born-Oppenheimer approximation breaks down; this causes electromagnetic coupling between SP electrons and protons, deuterons, or tritons associated with a 'patch' and enables local nuclear-strength, collective electric fields > 2 x 10^{11} V/m to be created therein; such a 'patch' is akin to a 'naked' pancake-shaped nucleus
- ✓ 'Patch' SP electrons locally bathed in nuclear-strength electric fields undergo what is called "mass renormalization," that is, their masses effectively increase. This effect that our condensed matter theory of LENRs relies upon first discovered and published by famous Russian physicists back 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)

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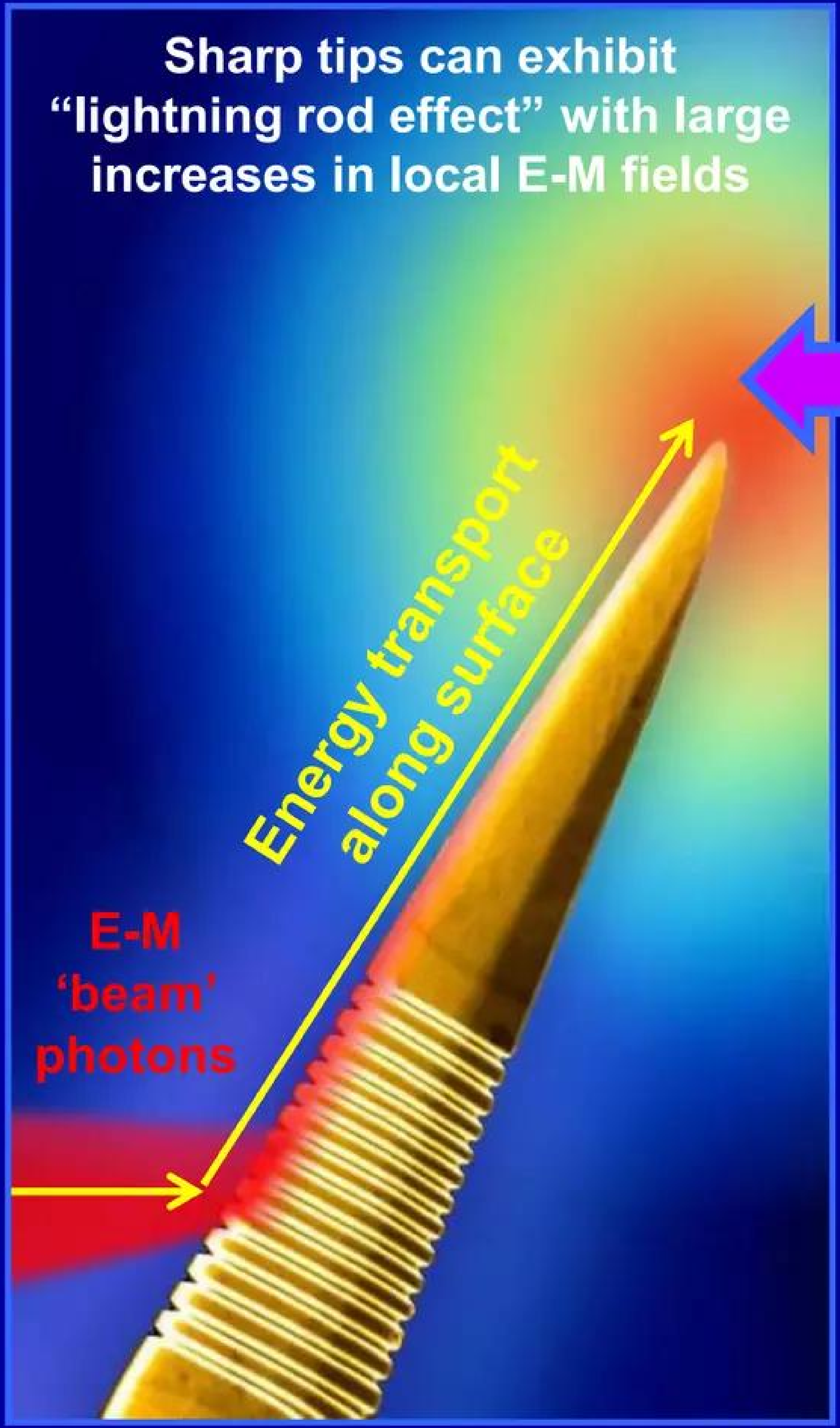
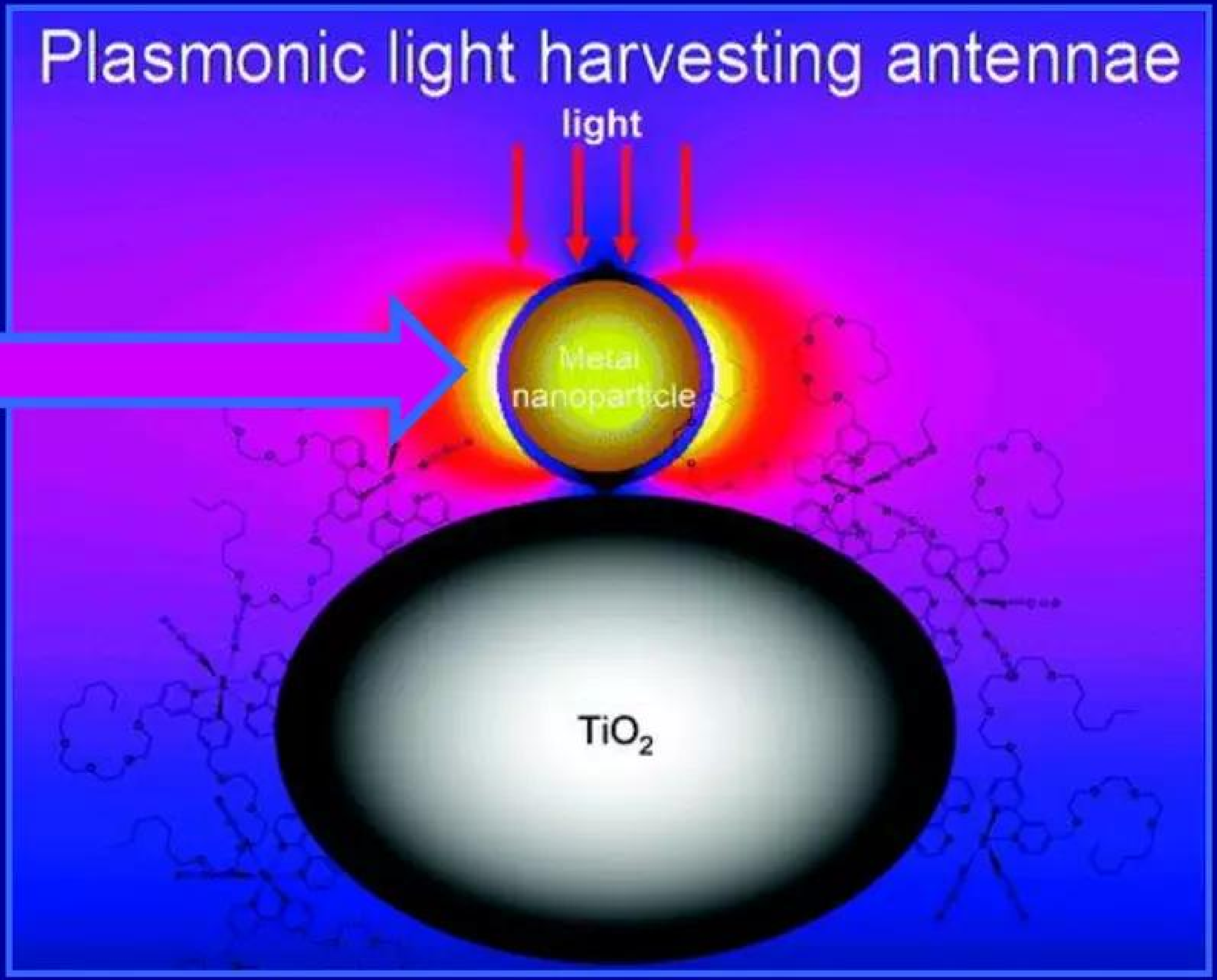
Surface plasmons can absorb, transport, concentrate, and store input energy



Sharp tips can exhibit “lightning rod effect” with large increases in local E-M fields

Region of enhanced E-M fields



http://people.ccmr.cornell.edu/~uli/res_optics.htm

Source of above image is the Wiesner Group at Cornell University:

See: “Plasmonic dye-sensitized solar cells using core-shell metal-insulator nanoparticles," M. Brown *et al*., *Nano Letters* 11 (2) pp. 438 - 445 (2011)   http://pubs.acs.org/doi/abs/10.1021/nl1031106

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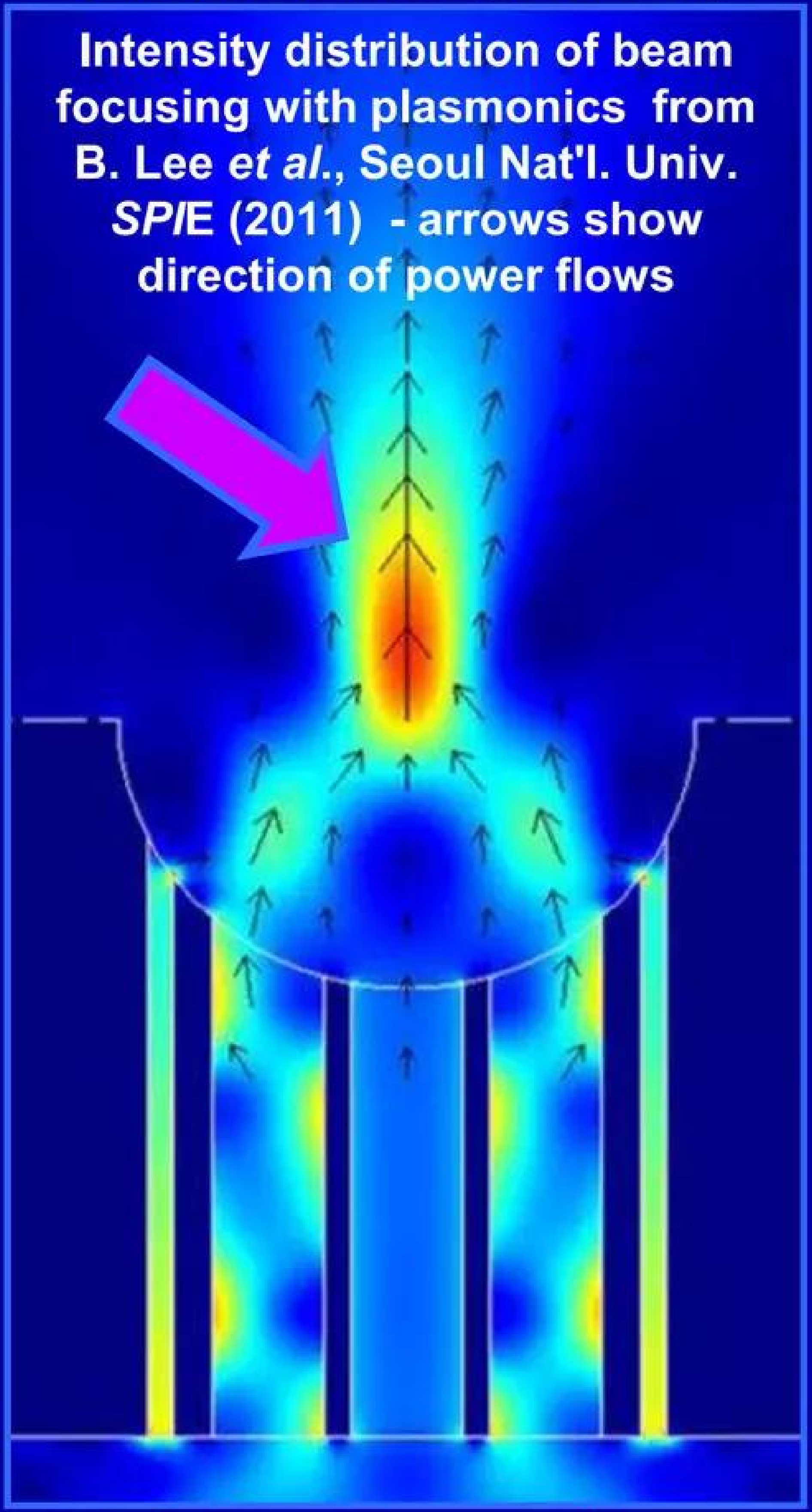
Surface plasmons can absorb, transport, concentrate, and store input energy

Concentrating E-M energy in resonant electromagnetic cavity



Intensity distribution of beam focusing with plasmonics from B. Lee *et al.*, Seoul Nat'l. Univ. *SPI*E (2011) - arrows show direction of power flows

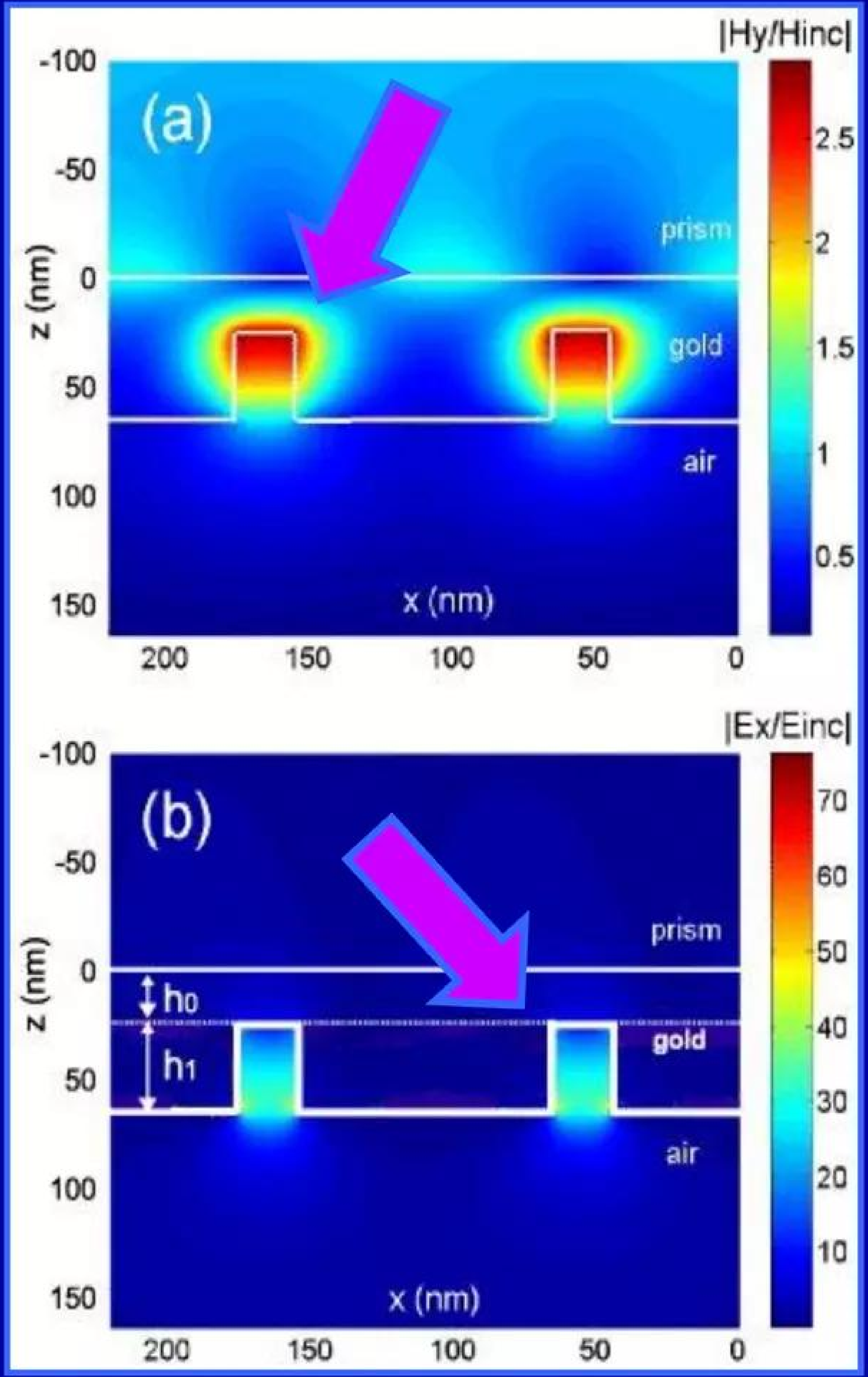
http://spie.org/documents/Newsroom/Imported/003435/003435_10.pdf

Reference:

"Enhancing reactive energy through dark cavity plasmon modes"
J. Le Perchec
***Europhysics Letters* 92 DOI: 10.1209/0295-5075/92/67006 (2010)**

Abstract:

"We present an opto-geometrical configuration in which a metallic surface having nanometer-scale grooves can be forced to efficiently resonate without emitting radiation. The structure is excited from the backside, by an evanescent wave, which allows to inhibit light re-emission and to drastically modify the quality factor of the resonance mode. The energy balance of the system, especially the imaginary part of the complex Poynting vector flux, is theoretically analysed thanks to a modal method. It is shown how the generated hot spots (coherent cavity modes of electro-static type) can store a great amount of unused reactive energy. This behaviour might thus inspire a novel use of such highly sensitive surfaces for chemical sensing."



Credit: J. Le Perchec

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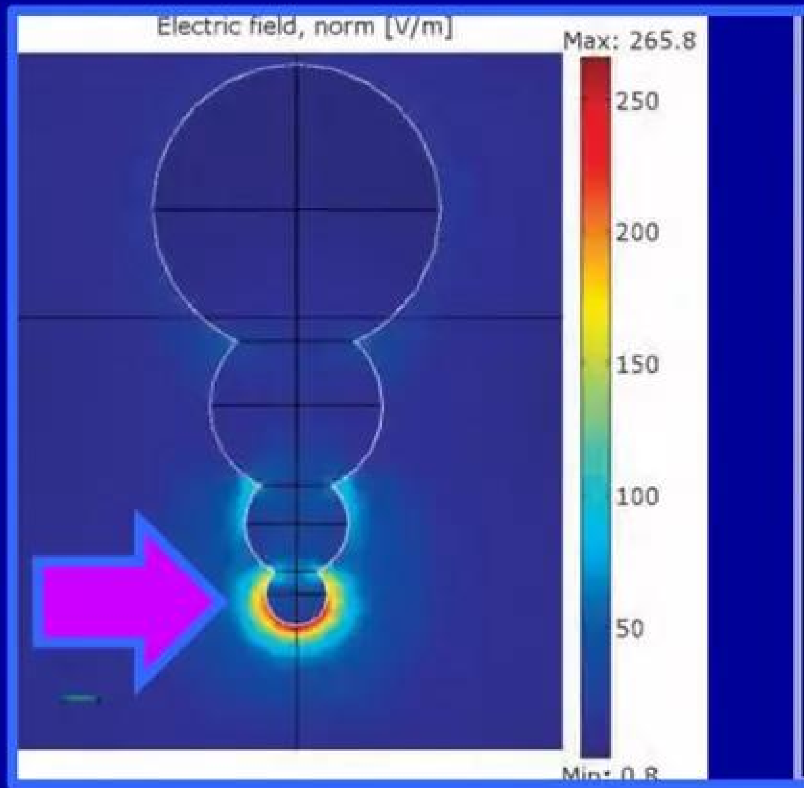
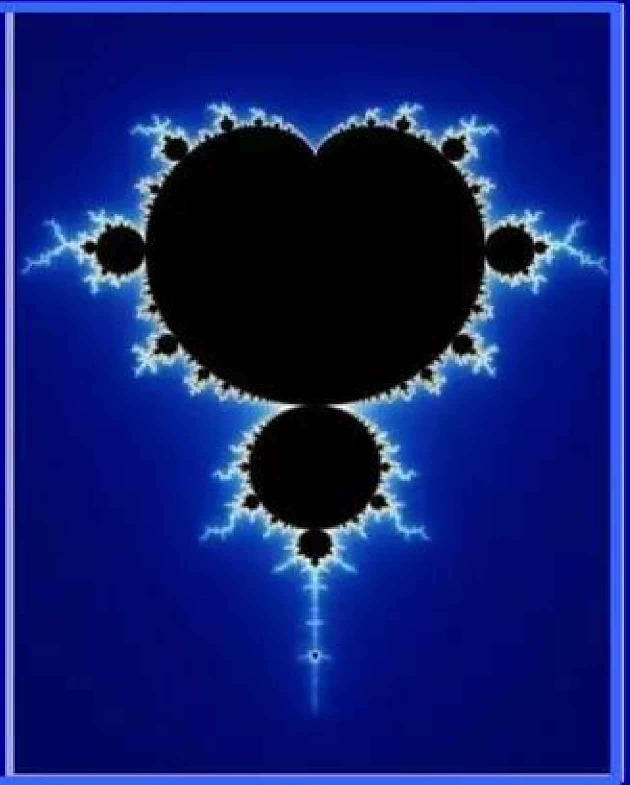
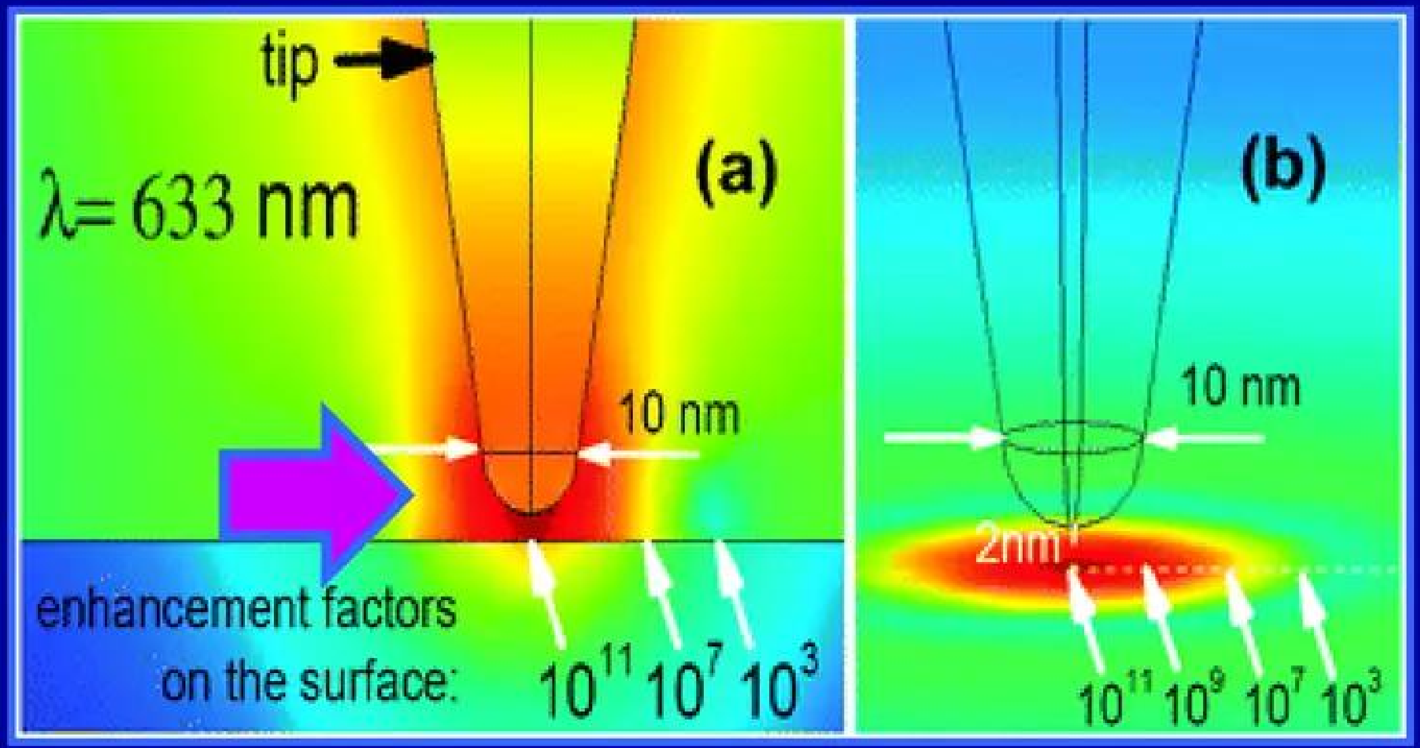
Local E-fields can increase drastically between nanoparticles and at sharp tips



Electric field enhancement at nano-antenna tip: R. Kappeler *et al.*, 2007

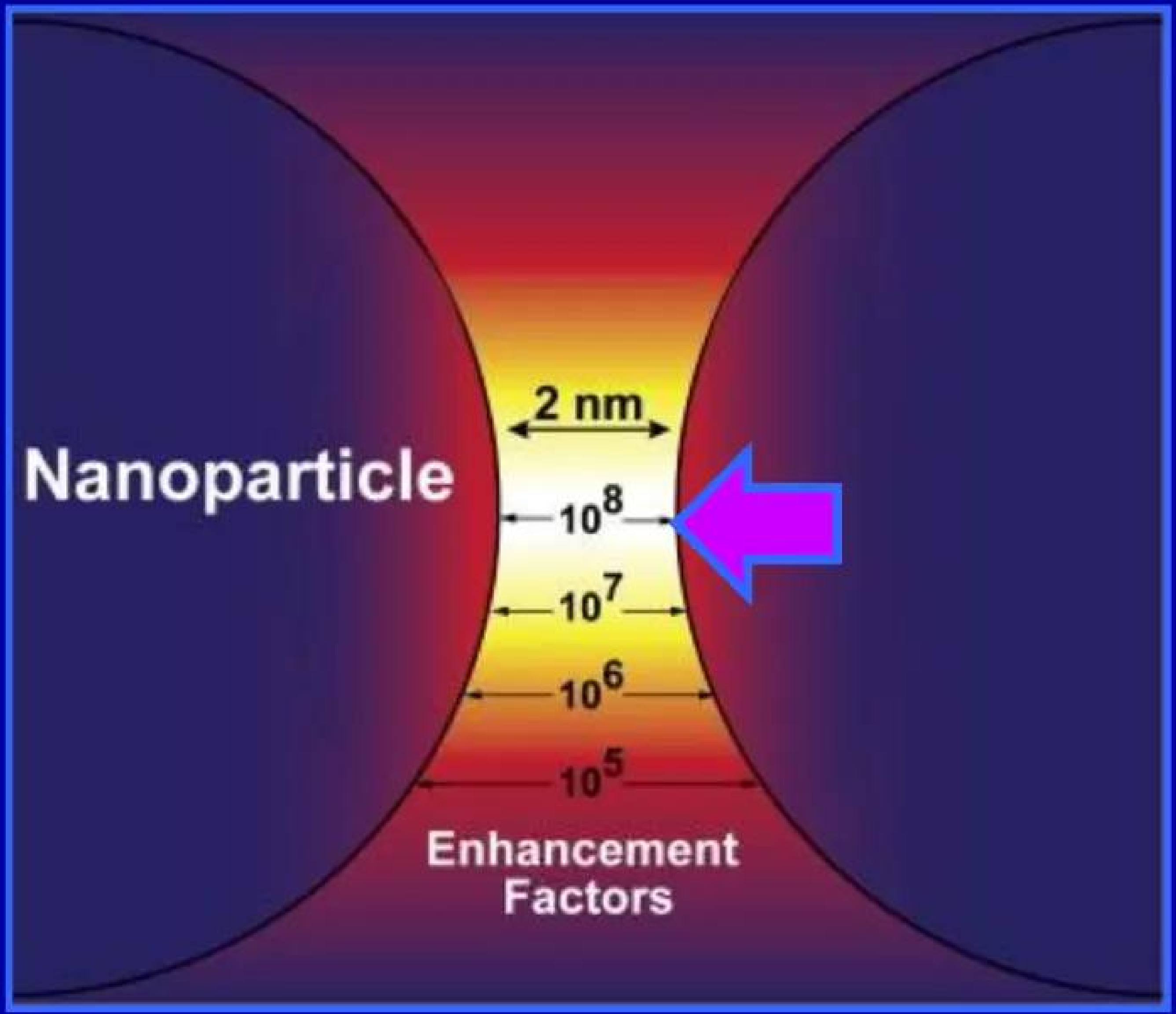


<u>Above</u>: classic Mandelbrot fractal form



Sharp tips can exhibit the so-called "lightning rod effect" in terms of local enhancement of electric field strengths

E-M field strength enhancement as a function of interparticle spacing



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Stars, fission reactors, tokamaks, and thermonuclear explosions - not required

LENR field-energy processes unlike few-body kinetic processes in fusion plasmas

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

- ✓ **Comparatively cool, collective many-body aikido field-energy process in condensed matter LENRs contrasts sharply with few-body taekwondo kinetic processes that occur in stellar, tokamak, *Z*-pinch, and ICF fuel 'target' fusion plasmas where charged particles, e.g. d^+ and t^+, are heated to enormous temperatures so a small subset (high-energy 'tail' of Maxwellian distribution of particle energies) of them that strike each other head-on have enough kinetic energy to surmount the Coulomb energetic barrier (like charges repel each other) to nuclear fusion reactions**

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Stars, fission reactors, tokamaks, and thermonuclear explosions - not required

Here is how LENRs avoid producing deadly fluxes of energetic neutrons:

- ✓ **Unlike energetic neutrons typically produced in nuclear reactions, collectively produced LENR neutrons are ~ 'standing still' at the moment of creation in condensed matter. Since they are vastly below thermal energies (i.e., ultra low momentum), ULM neutrons have huge Q-M DeBroglie wavelengths and commensurately large capture cross-sections on nearby nuclei; virtually all will be locally absorbed – only very rarely will some be detectable as *minute* fluxes of 'free' neutrons**
- ✓ **For vast majority of stable and unstable isotopes, effective neutron capture cross-sections (relative to measured cross-sections at thermal energies where v = 2,200 m/sec and DeBroglie wavelength is ~ 2 Angstroms) are directly related to ~1/v, where v is neutron velocity in m/sec. Since v in m/sec is negligible for ULM neutrons, their 1/v capture cross-sections on nuclei will be proportionately larger. After being created via aikido, virtually all ULMNs will be locally captured before scattering on lattice atoms elevates them to thermal kinetic energies**

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Stars, fission reactors, tokamaks, and thermonuclear explosions - not required

Here is how LENRs avoid producing deadly fluxes of gamma radiation:

- ✓ **Dynamic process whereby unreacted heavy-mass SP electrons in LENR-active 'patches' can actively absorb and directly convert locally emitted or incident gamma radiation into many more less-energetic infrared (IR) photons at high efficiency while, of course, obeying the law of conservation of energy (has tiny, highly variable soft X-ray 'tail')**
- ✓ **When ULM neutron captures onto an atom located inside entangled 3-D Q-M domain of an LENR-active patch, there are normally prompt gamma photon emissions by the atom. Since this capture-related gamma radiation occurs INSIDE the 3-D quantum mechanical structure of a 3-D LENR-active 'patch', there are always heavy electrons available nearby to absorb and convert such gamma emissions into IR. It doesn't matter *where* a gamma occurs inside a 'patch', it will always get converted; ditto for gammas associated with *β*-decays of local LENR transmutation products. Large fluxes of MeV gammas will not be emitted externally from such patches, no matter what x-y-z direction it is measured from**

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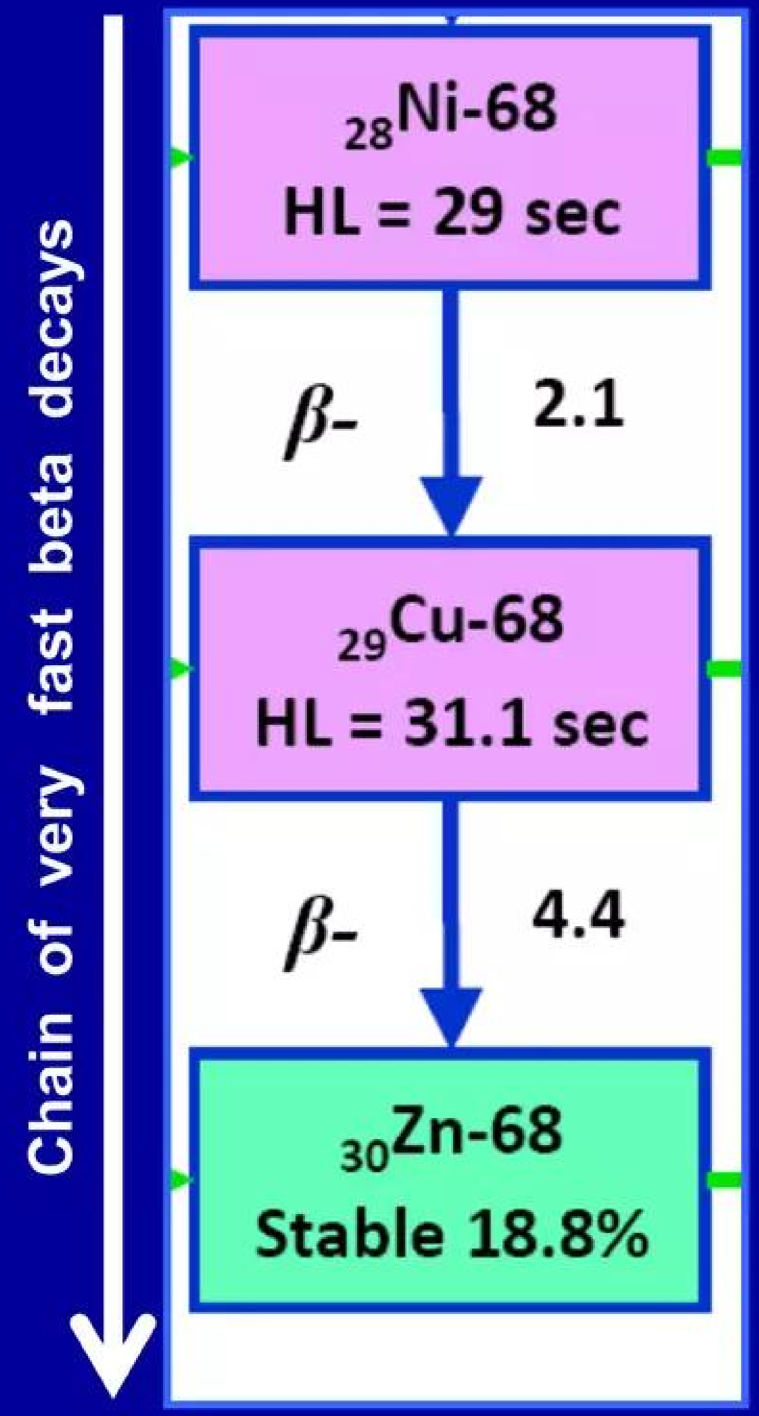
Stars, fission reactors, tokamaks, and thermonuclear explosions - not required

Here is how LENRs avoid producing hazardous long-lived radioactive isotopes:

- ✓ **Fluxes of ULM neutrons will cause a build-up of local populations of unstable, very neutron-rich isotopes comprising intermediate LENR transmutation products**
- ✓ **At some point during limited lifetime of an LENR-active 'patch', almost all such isotopes present in it will decay, mainly by series of very rapid *β*-decay cascades**
- ✓ **Depending on the half-lives (HL) of intermediate LENR products, ULMN captures + *β*-decay chains can rapidly traverse entire rows of the periodic table, finally ending with production of almost invariably stable isotopes of higher-Z elements (see simple example to right)**
- ✓ ***β*-decay cascades are reason why LENR typically do not produce biologically significant amounts of "radwaste"**



Nickel-68, a product of neutron captures on stable Nickel isotopes, decays rapidly to stable Zinc

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Breakdown of Born-Oppenheimer is important in condensed matter LENRs

Phenomenon is well-established and measured experimentally:

- ✓ **Born-Oppenheimer approximation is now known to break down on surfaces of carbon fullerene structures and graphene (directly observed by Bushmaker *et al*., 2009);**
- ✓ **Carbon-arc experiments of Bockris & Sundaresan and Singh *et al.* (1994) provide evidence that that LENRs and the W-L ULM carbon-seed nucleosynthetic network can occur in presence of complex mixtures of fullerenes and graphene (see Larsen 9/3/09)**
- ✓ **Born-Oppenheimer is well known to break down on metal surfaces; quoting Yale Prof. John Tully, "Breakdown of the Born-Oppenheimer assumption is the rule rather than the exception in electron transfer reactions, photochemistry, and reactions at metal surfaces." (please see his website at right)**
- ✓ **Born-Oppenheimer also known to break down in benzene rings in conjunction with quantum entanglement of protons on those rings (see Chatzidimitriou- Dreismann & Mayers, 2002). Quoting from their paper, "… our NCS results …indicate that the physical meaning of … Born-Oppenheimer [approximation] should be critically reconsidered … at least for chemical processes in the …femtosecond time scale … [we also] demonstrate that short-lived protonic quantum entanglement and decoherence are of much broader significance than realized thus far."**

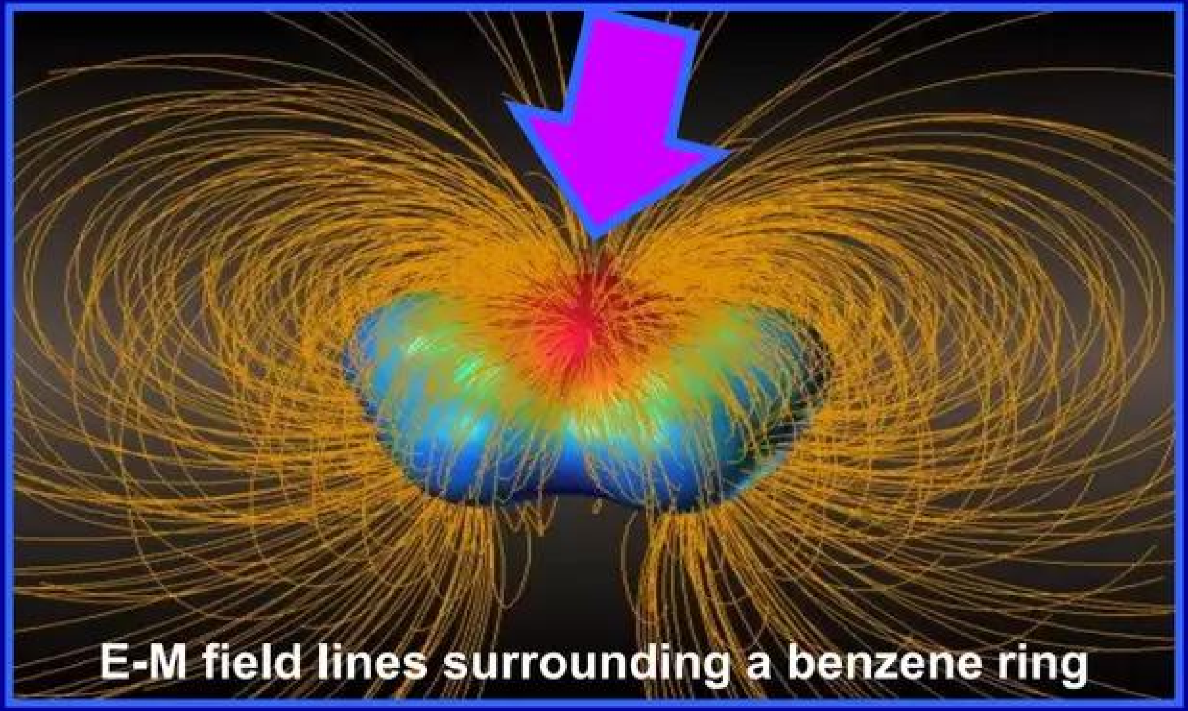
→ **"Direct observation of Born-Oppenheimer approximation breakdown in carbon nanotubes"**
Bushmaker *et al.*
***Nano Letters* 9 pp. 607 (2009)**

→ **See Lattice Energy LLC SlideShare presentation dated September 3, 2009, at:**

http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewcarbon-seed-lenr-networkssept-3-2009

→ **See Prof. Tully's Yale website at:**
http://www.chem.yale.edu/~tully/research.html

→ **"Sub-femtosecond dynamics and dissociation of C-H bonds in solid polystyrene and liquid benzene"**
C. Chatzidimitriou-Dreismann & Mayers
***Journal of Chemical Physics* 116 pp. 1617-1623 (2002)**



E-M field lines surrounding a benzene ring

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Many-body collective & quantum effects crucial to aikido

Many-body collective effects and quantum entanglement work together

✓ Many-body collective oscillations and mutual quantum entanglement of protons (as well as deuterons and tritons) and electrons (e.g., SPs on metallic hydride surfaces), in conjunction with a breakdown of the Born-Oppenheimer approximation, appear to be relatively common in nature, occurring in many different types of physical systems

✓ While these many-body collective processes chronicled by Chatzidimitriou-Dreismann *et al.* operate very rapidly and nanoscale Q-M coherence can only persist for time spans on the order of femtoseconds (10^{-15} sec) to attoseconds (10^{-18} sec), nuclear processes such as weak interaction ULM neutron production and neutron capture operate on even faster time-scales: 10^{-19} to 10^{-22} sec. Therefore, LENRs as explained by the Widom-Larsen theory can easily take advantage of such many-body collective quantum effects as an integral part of their amazing dynamical repertoire

✓ It is well-known that metallic surface nanostructures and SP electrons can have configurations that are able to effectively absorb E-M energy over a wide area, transfer and concentrate it, and in conjunction with contiguous surface 'patches' of collectively oscillating protons, create nuclear-strength local electric fields. According to W-L theory of LENRs, electroweak neutron production can then follow

→ C. Chatzidimitriou-Dreismann (Technical University of Berlin) and his collaborators have published extensively on collective proton dynamics since 1995. Please also see:

"Attosecond quantum entanglement in neutron Compton scattering from water in the keV range" (2007); can be found at

http://arxiv.org/PS_cache/cond-mat/pdf/0702/0702180v1.pdf

"Several neutron Compton scattering (NCS) experiments on liquid and solid samples containing protons or deuterons show a striking anomaly, i.e. a shortfall in the intensity of energetic neutrons scattered by the protons; cf. [1, 2, 3, 4]. E.g., neutrons colliding with water for just 100 - 500 attoseconds (1 as = 10^{-18} s) will see a ratio of hydrogen to oxygen of roughly 1.5 to 1, instead of 2 to 1 corresponding to the chemical formula H_2O. … Recently this new effect has been independently confirmed by electron-proton Compton scattering (ECS) from a solid polymer [3, 4, 5]. The similarity of ECS and NCS results is striking because the two projectiles interact with protons via fundamentally different forces, i.e. the electromagnetic and strong forces."

→ Also: *"Entangled mechanical oscillators,"* J. Jost *et al.*, *Nature* 459 pp. 683 - 685 4 (2009) in which, "... mechanical vibration of two ion pairs separated by a few hundred micrometres is entangled in a quantum way."

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Many-body collective & quantum effects crucial to aikido

Mutual Q-M entanglement of protons and electrons observed experimentally

Phenomenon is well-established; measured experimentally:

✓ **Protons found within a wide variety of many-body molecular systems spontaneously oscillate coherently/collectively; their quantum mechanical (QM) wave functions are thus effectively entangled with each other and also with nearby collectively oscillating electrons; amazingly, this behavior occurs even in comparatively 'smaller,' 'simpler' molecular systems such as $(NH_4)_2PdCl_6$, ammonium hexaclorometallate (see Krzystyniak *et al*., 2007 and Abdul-Redah & Dreismann, 2006). Quoting from the paper by Krzystyniak *et al*., "… different behaviors of the observed anomaly were found for LaH_2 and LaH_3 … As recognized by Chatzidimitriou-Dreismann *et al.* Coulombic interaction between electrons and protons may build up entanglement between electrons and protons. Such many body entangled states are subject to decoherence mechanisms due to the interaction of the relevant scattering systems with its environment … one can conclude that the vibrational dynamics of NH_4^+ protons as fairly well decoupled from the dynamics of the [attached] heavier nuclei."**

✓ **Elaborating further from Chatzidimitriou-Dreismann (2005), "Further NCS experiments confirmed the existence of this effect in quite different condensed matter systems, e.g., urea dissolved in D_2O, metallic hydrides, polymers, 'soft' condensed matter, liquid benzene, and even in liquid H_2-D_2 and HD."**

→ **"Anomalous neutron Compton scattering cross sections in ammonium hexachlorometallates," Krzystyniak *et al., Journal of Chemical Physics* 126 pp. 124501 (2007)**

→ **"Irreversible hydrogen quantum dynamics and anomalous scattering behavior in liquids and solids," Abdul-Redah & Chatzidimitriou-Dreismann*, International Journal of Hydrogen Energy* 31 pp. 269 - 276 (2006)**

→ **"Attosecond protonic quantum entanglement in collision experiments with neutrons and electrons," C. Chatzidimitriou-Dreismann, *Laser Physics* 15 pp. 780 -788 (2005)**

→ **Please also see book chapter by Chatzidimitriou-Dreismann *et al.*, "Attosecond effects in scattering of neutrons and electrons from protons", in Decoherence, Entanglement, and Information Protection in Complex Quantum Systems, Akulin *et al.* eds., NATO Science Series II Vol. 189 Springer Netherlands (2005)**

With regard to direct experimental evidence that surface plasmons are quantum mechanically entangled, see:

→ ***"*Plasmon-assisted transmission of entangled photons,*"* E. Altewischer *et al., Nature* 418 pp. 304 - 306 (2002); quoting from it, "Our coincidence counting measurements show that it does [quantum entanglement of photons survives its conversion to surface plasmons], so demonstrating that surface plasmons have a true quantum nature … simple estimate shows that SPs are very macroscopic, in the sense that they involve 10^{10} electrons . Our experiment proves that this macroscopic nature does not impede the quantum behavior of SPs… "**

http://www.molphys.leidenuniv.nl/~exter/articles/nature.pdf

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Mutual Q-M entanglement of protons and electrons observed experimentally

“Evidence of macroscopically entangled protons in a mixed isotope crystal of $KH_pD_{1-p}CO_3$”
F. Fillaux, A. Cousson, and M. Gutmann
Journal of Physics - Condensed Matter **22 pp. 045402 (2010)**
http://hal.archives-ouvertes.fr/docs/00/44/62/16/PDF/Fillaux.pdf

Quoting directly:

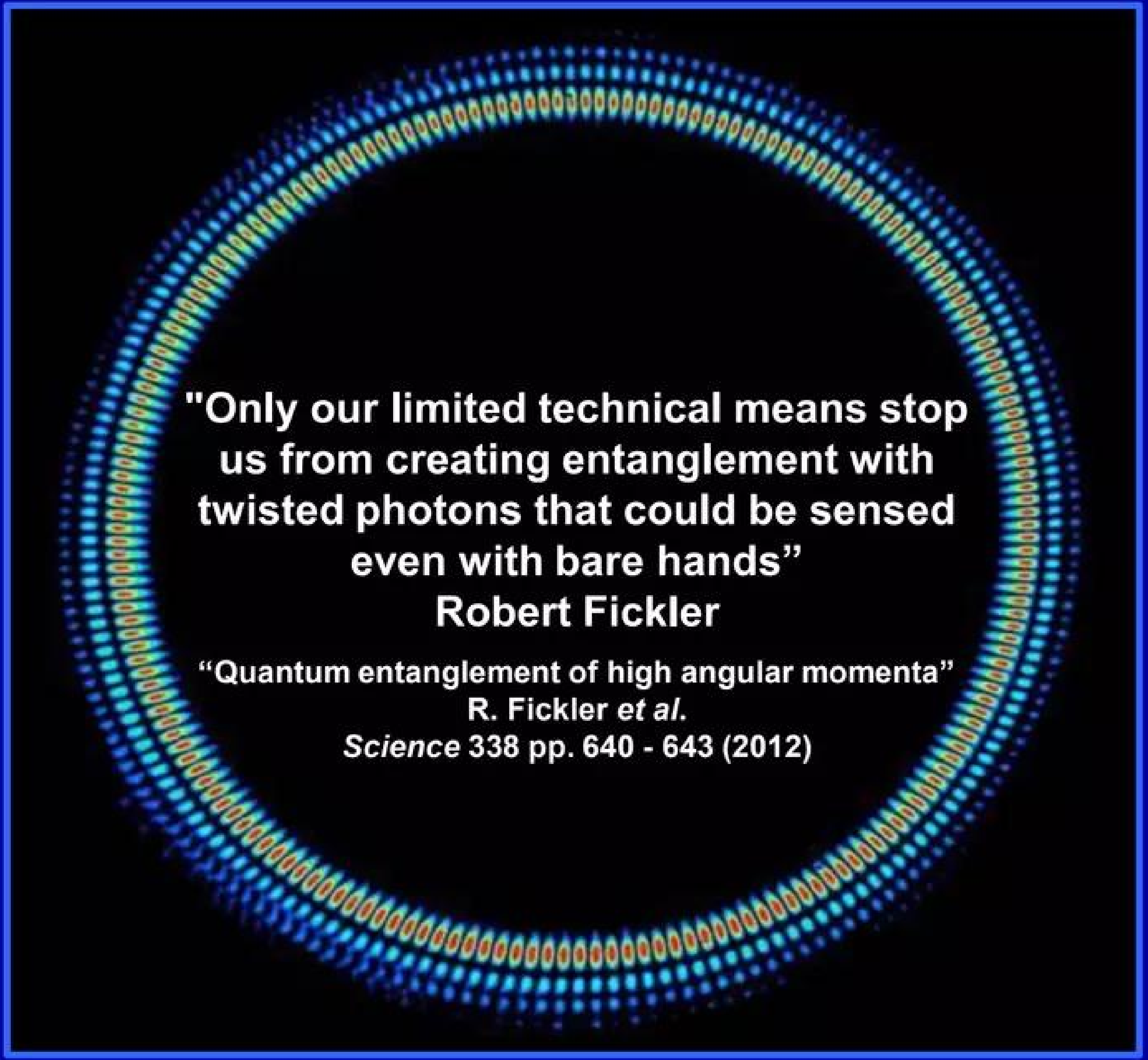
“The proposed theory is based upon fundamental laws of quantum mechanics applied to the crystal in question: the structure is periodic; dimers are centrosymmetric; indistinguishable protons are fermions; indistinguishable deuterons are bosons. It leads to macroscopically entangled states and, in the special case of protons, to super-rigidity and spin-symmetry with observable consequences. This theory is consistent with a large set of experimental data (neutron diffraction, QENS, INS, infrared and Raman) and, to the best of our knowledge, there is no conflict with any observation. There is, therefore, every reason to conclude that the crystal is a macroscopic quantum system for which only nonlocal observables are relevant.”

“Protons are unique to demonstrating quantum entanglement, because they are fermions and because the very large incoherent cross-section can merge into the total coherent cross-section. No other nucleus can manifest such an increase of its coherent cross-section. The enhanced features can be, therefore, unambiguously assigned to protons, in accordance with their positions in reciprocal space. They are evidences of macroscopic quantum correlations which have no counterpart in classical physics.”

“This work presents one single case of macroscopically entangled states on the scale of Avogadro's constant in a mixed isotope crystal at room temperature. The quantum theory suggests that such macroscopic quantum effects should be of significance for many hydrogen bonded crystals.”

Also please see:

“A neutron diffraction study of macroscopically entangled proton states in the high temperature phase of the $KHCO_3$ crystal at 340 K”
F. Fillaux, A. Cousson, and M. Gutmann
Journal of Physics - Condensed Matter **20 pp. 015225 (2008)**
http://www.ladir.cnrs.fr/pages/fillaux/159_JPCM_2008_015225.pdf



"Only our limited technical means stop us from creating entanglement with twisted photons that could be sensed even with bare hands”
Robert Fickler

“Quantum entanglement of high angular momenta”
R. Fickler *et al.*
Science **338 pp. 640 - 643 (2012)**

False Color Image of Laser Beam Superimposition of Entangled Photons
Credit: R. Fickler, Univ. of Vienna

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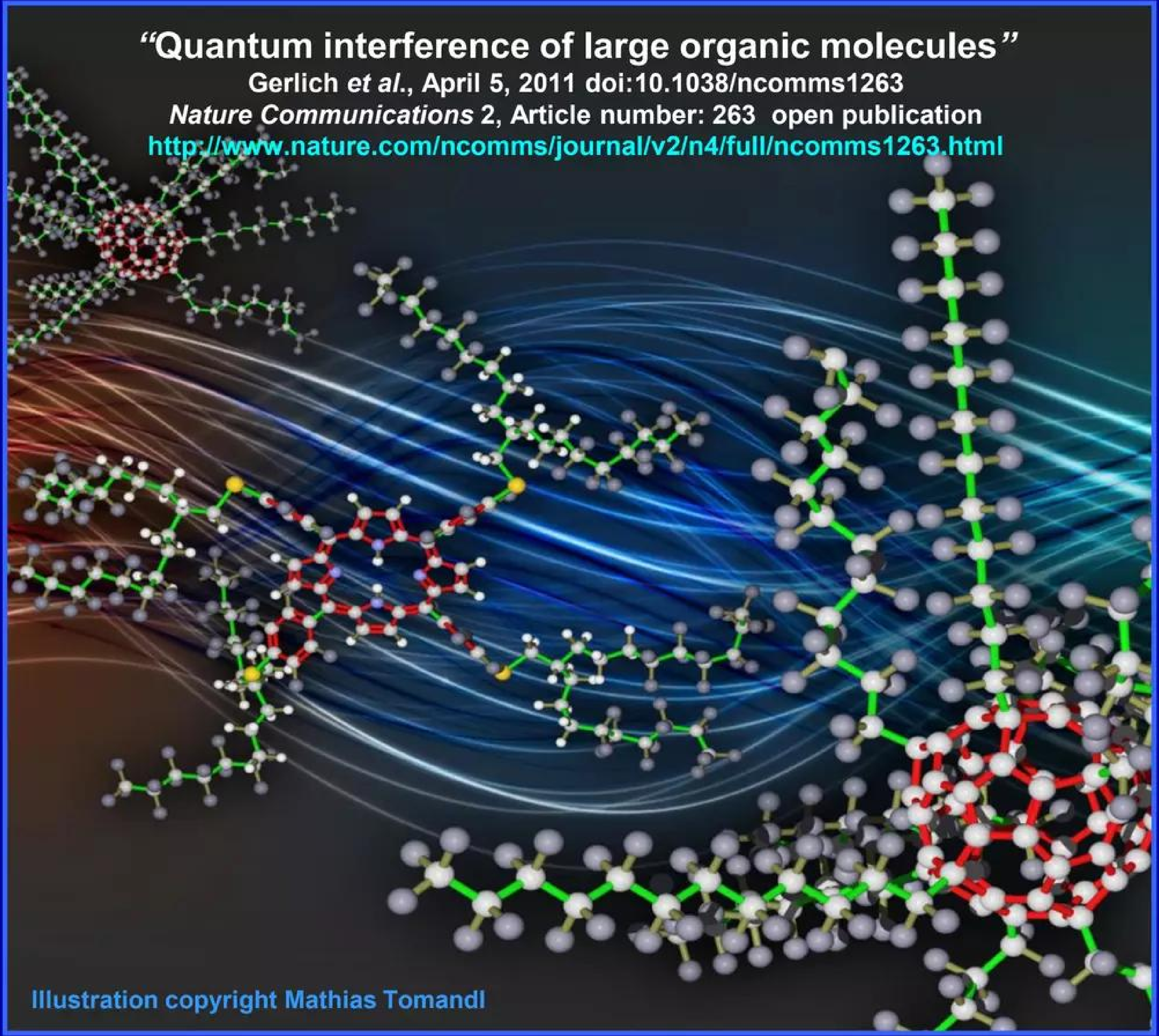
Many-body collective & quantum effects crucial to aikido

Quantum entanglement observed in surprisingly large molecular ensembles

"PFNS10 and TPPF152 contain 430 atoms covalently bound in one single particle. This is $\sim$350% more than that in all previous experiments and it compares well with the number of atoms in small Bose–Einstein condensates (BEC), which, of course, operate in a vastly different parameter regime: The molecular de Broglie wavelength λ_{dB} is about six orders of magnitude smaller than that of ultracold atoms and the internal molecular temperature exceeds typical BEC values (T<1 μK) by about nine orders of magnitude. Although matter wave interference of BECs relies on the de Broglie wavelength of the individual atoms, our massive molecules always appear as single entities."



*"*Quantum interference of large organic molecules*"*

Gerlich *et al.*, April 5, 2011 doi:10.1038/ncomms1263

Nature Communications 2, Article number: 263 open publication

http://www.nature.com/ncomms/journal/v2/n4/full/ncomms1263.html

Illustration copyright Mathias Tomandl

Artistic view of most complex and massive molecules (PFNS-10, TPP-152) brought to quantum interference by Gerlich *et al.* (2011)

"Our experiments prove the quantum wave nature and delocalization of compounds composed of up to 430 atoms, with a maximal size of up to 60 Å, masses up to *m*=6,910 AMU and de Broglie wavelengths down to $\lambda_{dB}=h/mv \simeq 1$ pm ... In conclusion, our experiments reveal the quantum wave nature of tailor-made organic molecules in an unprecedented mass and size domain. They open a new window for quantum experiments with nanoparticles in a complexity class comparable to that of small proteins, and they demonstrate that it is feasible to create and maintain high quantum coherence with initially thermal systems consisting of more than 1,000 internal degrees of freedom."

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1996: Miley reported very anomalous experimental results

Began with a pure Nickel cathode in an aqueous electrolytic chemical cell

Other elements found on Ni weeks later looked as though they had come out of a star

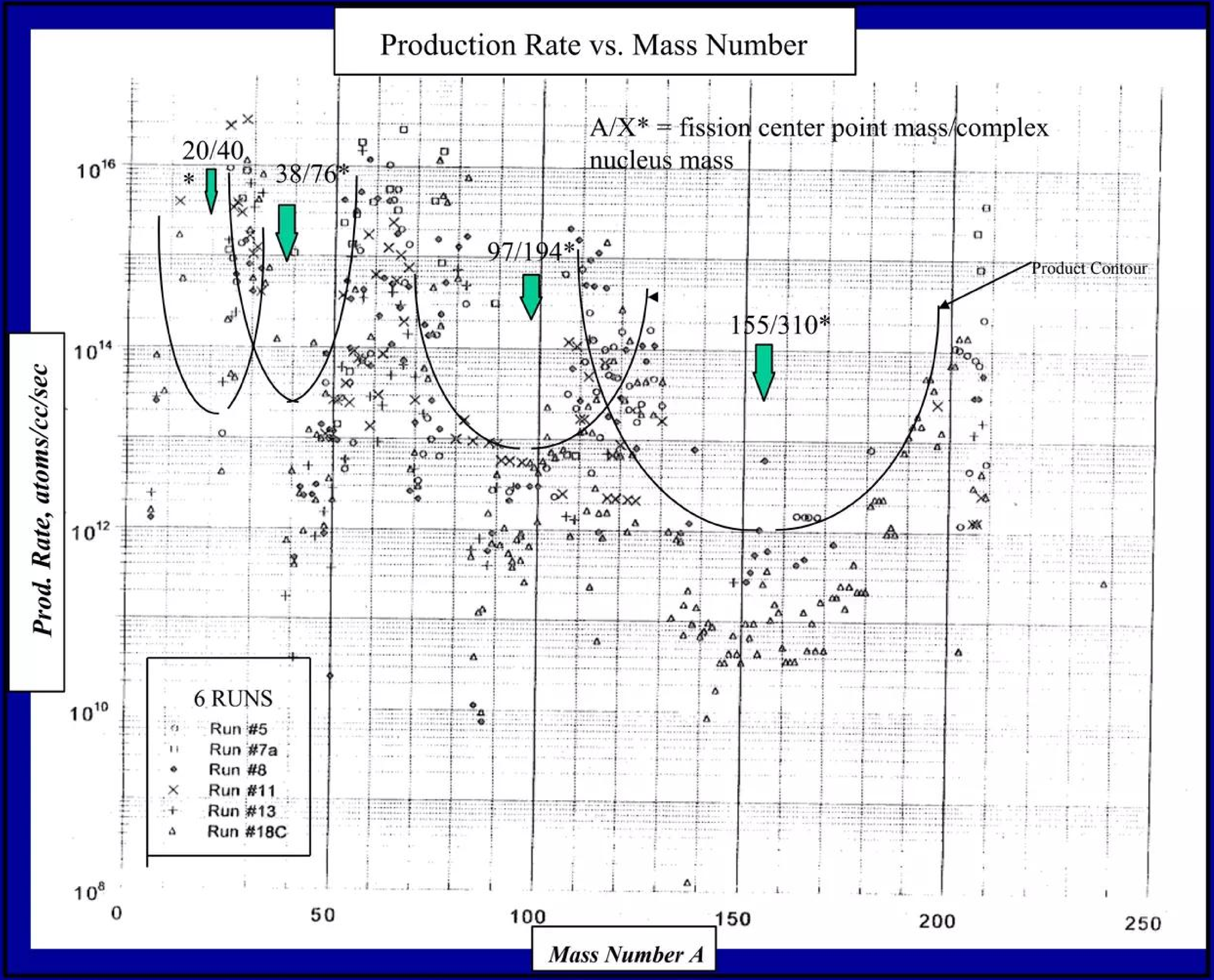
- ✓ **Experimental system was a prosaic current-driven electrolytic chemical cell having 1M $LiSO_4$-H_2O aqueous electrolyte; each experiment initially began operating with a 'fresh' pure Platinum (Pt) anode and a pure Nickel (Ni) planar cathode**
- ✓ **DC electric current was applied to a simple glass-beaker-type electrochemical cell that was run continuously for ~ two weeks**
- ✓ **At end of each such experimental run, Nickel cathode was removed from cell, sacrificed, and subjected to a variety of analytical techniques (e.g., neutron activation analysis, SIMS, EDX, etc.) to exhaustively assay for elements/isotopes present on and in a cathode at conclusion of a given experimental run**
- ✓ **When all of this measured data on observed elements and isotopes present was aggregated and plotted in the form of a graph with Atomic Mass (A) on the x-axis and measured production rate as a function of A on the y-axis, it revealed the presence of a unique 5-peak LENR transmutation product mass-spectrum that is shown in a graph found on the next slide**

- ✓ **Careful analysis of entire experimental system was performed to assess possibility of sources of external contamination; it was concluded that lab contamination cannot explain reported results**
- ✓ **T. Mizuno (Japan) observed *very similar* 5-peak LENR transmutation product mass spectrum when using a Palladium-cathode-D_2O current-driven chemical cell; this key fact suggested same causative mechanism for transmutation products**
- ✓ **Please see:**

  http://newenergytimes.com/v2/library/1996/1996Miley-QuantitativeObservation-ICCF6.pdf

1996: Miley reported very anomalous experimental results

Bewildering array of transmutation products exhibited 5-peak mass spectrum



Source: "Possible Evidence of Anomalous Energy Effects in H/D-Loaded Solids - Low Energy Nuclear Reactions (LENRs)," G. Miley *et al.*, *Journal of New Energy* 2 No. 3-4 pp. 6 - 13 (1997)

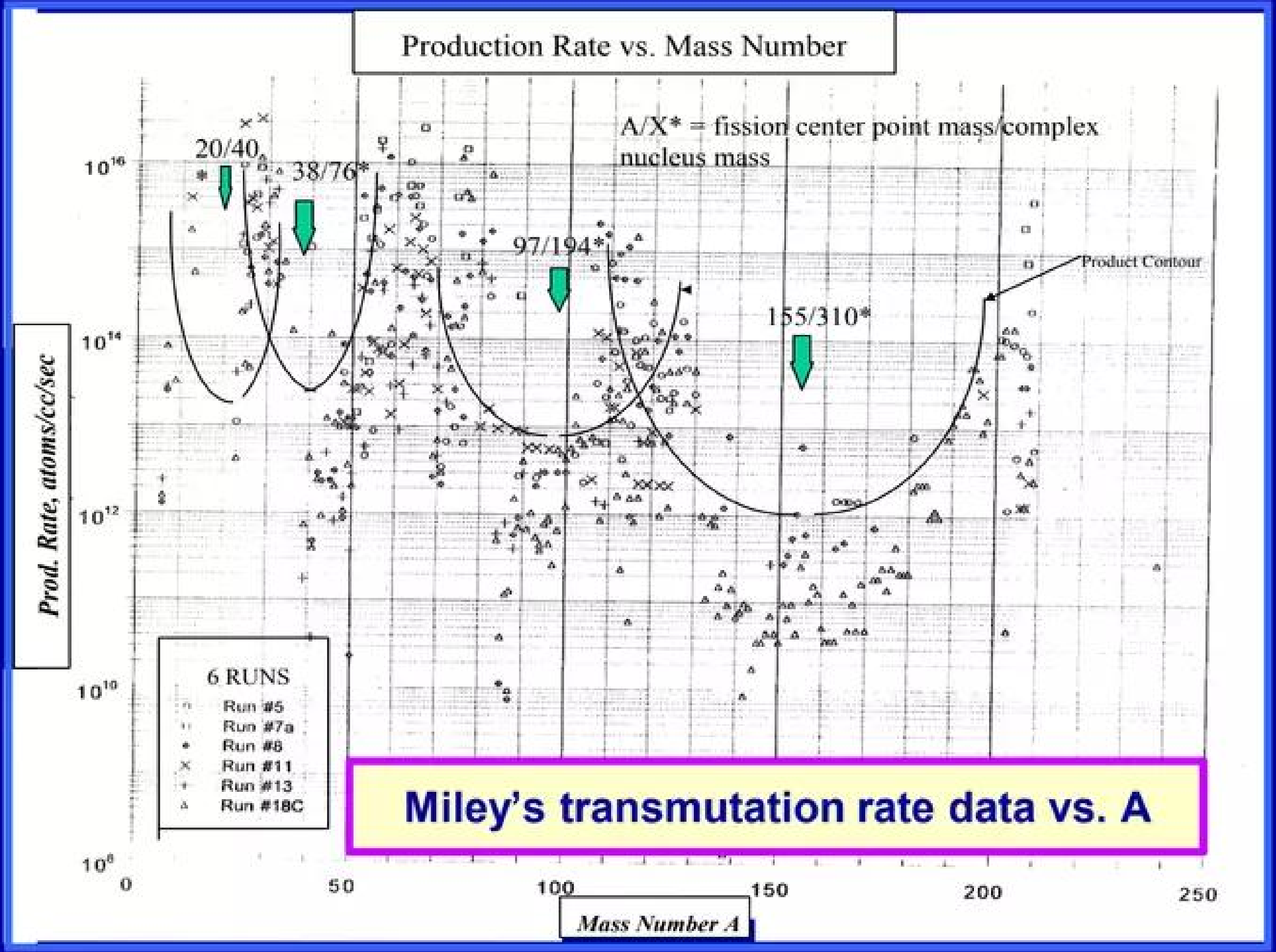
- ✓ **Five-peak transmutation product mass spectra reported by Miley was extremely anomalous; very unlike 2-peak fission-product mass spectra that is characteristic for fissionables like Uranium-235 or Plutonium-239**
- ✓ **Miley speculated that the observed 5 spectral peaks were the result of fission processes involving *ad hoc* hypothesized unstable, very neutron-rich compound nuclei at masses A = 40, 76, 194, and at 310, which was a conjectured superheavy element**
- ✓ **Unanswered issues with Miley's speculative explanation were: (a.) since the cathodes were Nickel (A~58) and Palladium (A~106), what nuclear process(es) occurred that produced the compound nuclei at A=194 and 310 from Pd and/or Ni ?; (b.) superheavy nuclei located at A=310 have not yet been observed experimentally**
- ✓ **Widom-Larsen explain this complex data with simple 2-parameter neutron optical potential theoretical model**

Powering the world to a green future

2006: Widom & Larsen explain Miley's 1996 - 1997 results

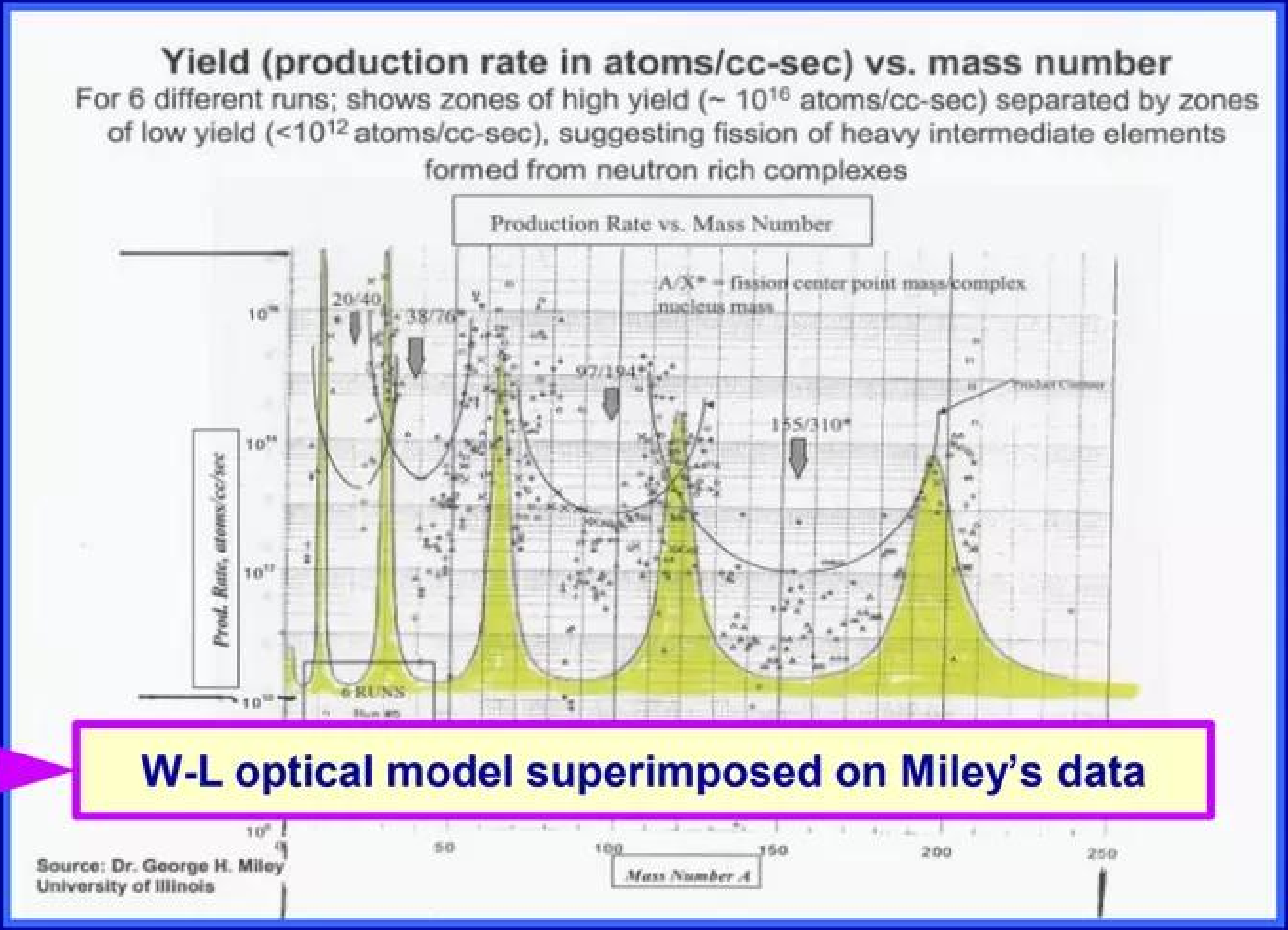
Optical potential model for LENR ULM neutron capture agrees well with data

- ✓ Top chart to right is Miley's raw data; chart below is same data only with results of W-L neutron optical potential model of ULMN neutron absorption by nuclei (yellow peaks) superimposed on top of Miley's data; good correspondence of Miley obs. vs. W-L calc.
- ✓ Model not fitted to data: *only* 'raw' calc output
- ✓ W-L model only generates a five-peak resonant neutron absorption spectrum at the zero momentum limit; neutrons at higher energies will not produce the same result
- ✓ This means that 5-peak product spectrum experimentally observed by Miley and Mizuno is a unique 'signature' of W-L ULM neutron production and absorption (capture) in LENRs



Miley's transmutation rate data vs. A

See: "Nuclear abundances in metallic hydride electrodes of electrolytic chemical cells" arXiv:cond-mat/0602472 (Feb 2006) A. Widom and L. Larsen


Yield (production rate in atoms/cc-sec) vs. mass number

For 6 different runs; shows zones of high yield (~ 10^{16} atoms/cc-sec) separated by zones of low yield ($<10^{12}$ atoms/cc-sec), suggesting fission of heavy intermediate elements formed from neutron rich complexes

W-L optical model superimposed on Miley's data

Source: Dr. George H. Miley University of Illinois

Powering the world to a green future

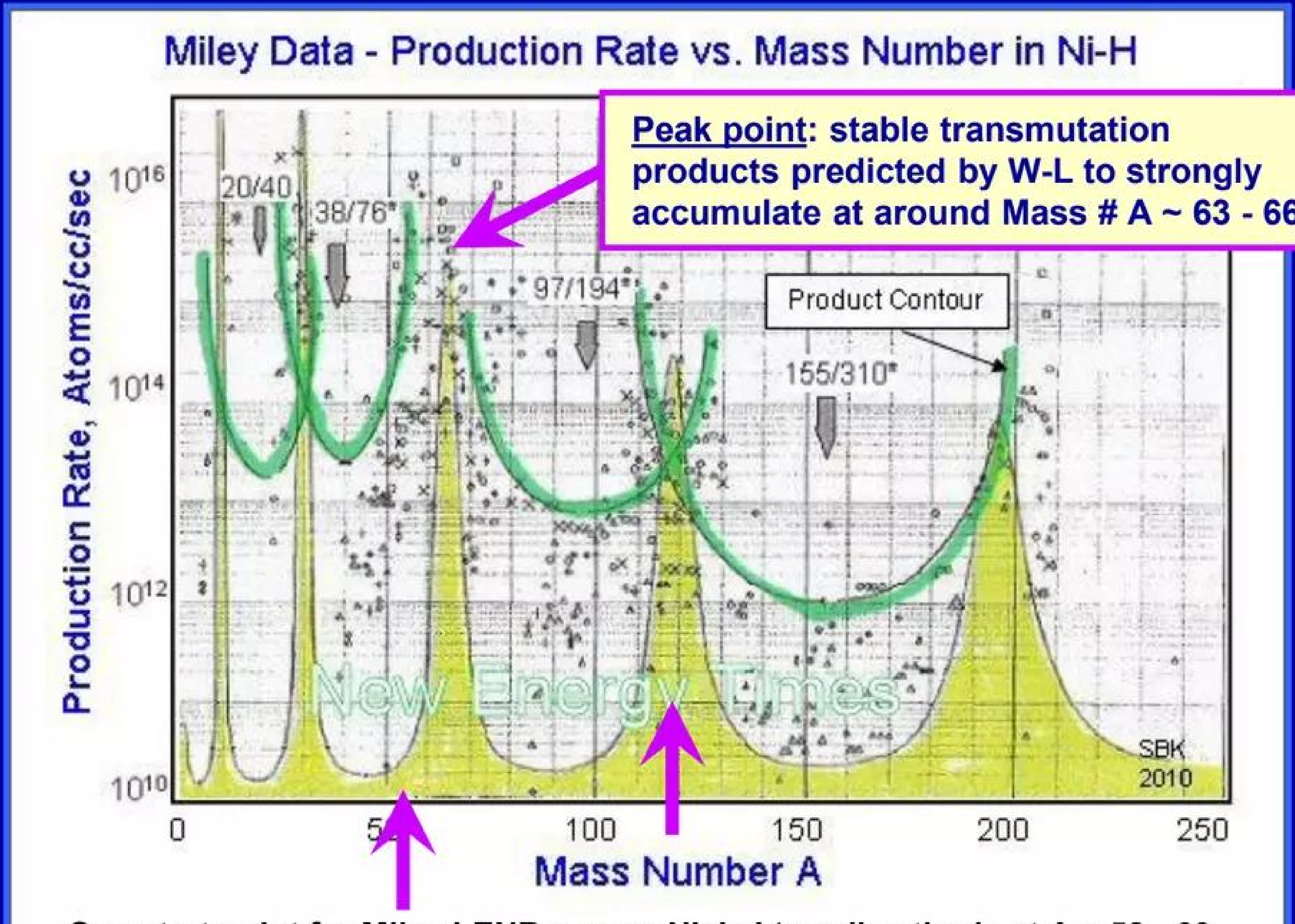
2006: Widom & Larsen explain Miley's 1996 - 1997 results

Five-peak mass spectrum is unique 'smoking gun fingerprint' of ULM neutrons

- ✓ W-L ULM optical neutron absorption model (2006) predicts a third stable product isotopic abundance peak at around mass # A ~63 - 66 (i.e., stable isotopes will tend to accumulate around that value of mass), that is, at around ~Cu thru ~Zn, which is clearly observed in Miley's 1996 experimental data shown to the right. The next major mass-peak number where somewhat larger quantities of stable LENR transmutation products are predicted by W-L to accumulate lies out at A ~120, which is also observed in Miley's (and Mizuno's) data

- ✓ Please recall that Miley's LENR production rate data by atomic mass came from multiple runs that lasted for up to two weeks; one of several starting 'seeds' for ULM neutron captures in Miley's experiments was a planar Nickel cathode comprised of (these are natural abundances):

Ni-58	~ 68.0%
Ni-60	~ 26.2%
Ni-61	~ 1.14%
Ni-62	~ 3.63%
Ni-64	~ 0.92%



Peak point: stable transmutation products predicted by W-L to strongly accumulate at around Mass # A ~ 63 - 66

One start point for Miley LENRs was a Nickel 'seed' cathode at A ~ 58 - 60

Upper 5-peak peak curve drawn by Miley in 1996 based on 6 experimental runs of transmutation yields from Ni-H LENR systems [1]. Lower curve, shaded in yellow, drawn by Larsen in 2000 with no fitting, based on Widom-Larsen ultra-low momentum neutron absorption model. [2]

1. Miley, G.H, and Patterson, James, "Nuclear Transmutations in Thin-Film Nickel Coatings Undergoing Electrolysis," Journal of New Energy, Vol. 1(3), pg. 5, (1996)
2. Larsen, Lewis, Feb. 7, 2009 slides

Source of modified graphic: ***New Energy Times***

Erratum: in fact, we drew the yellow curve showing our 'raw' model output in 2006, not in 2000 as Krivit states

Powering the world to a green future

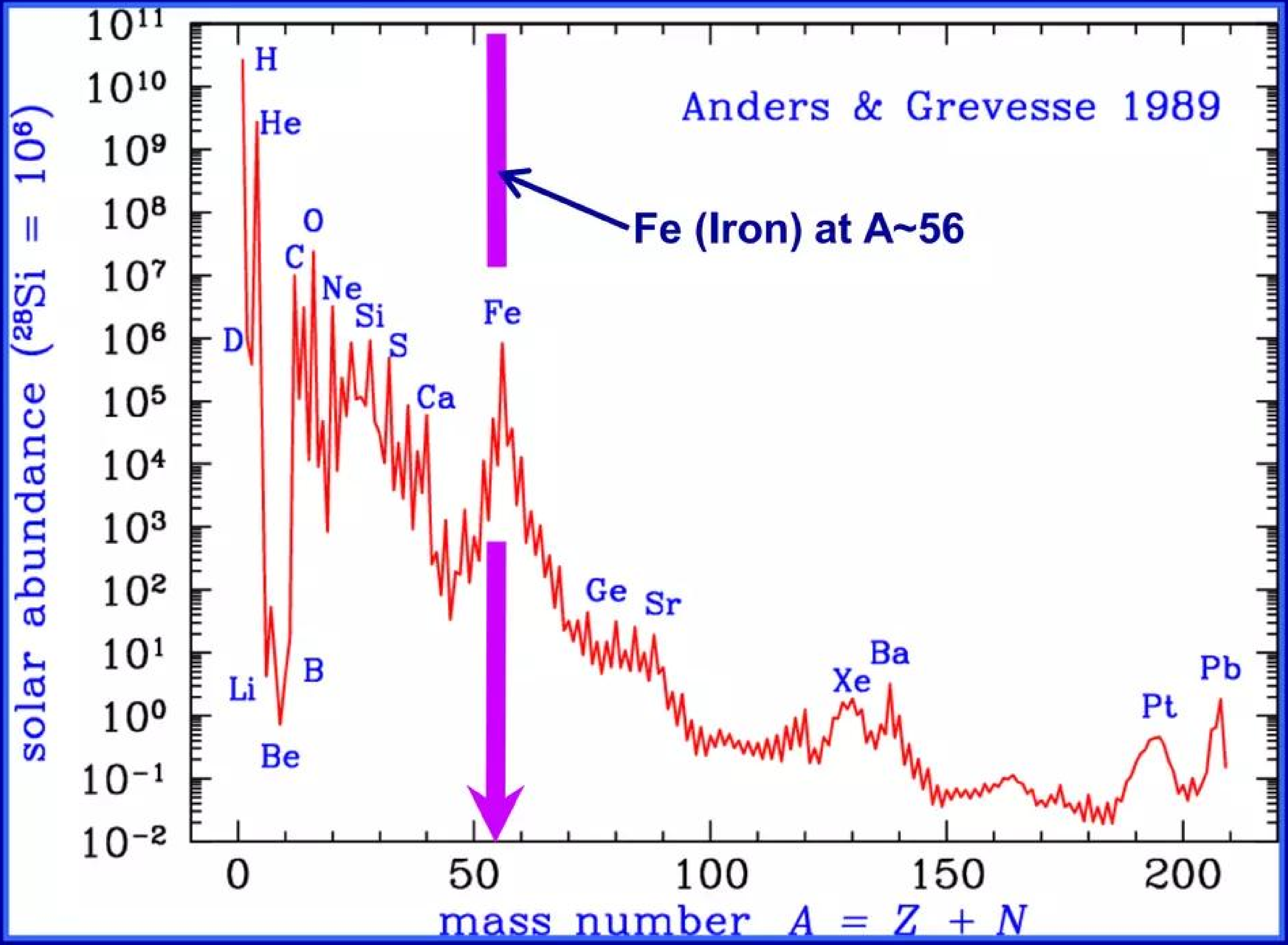
2006: Widom & Larsen explain Miley's 1996 - 1997 results

1996 Miley data directly compared to solar system elemental abundances

Solar abundance data reflects integrated cumulative results of stellar nucleosynthetic processes spread across distances of AUs to light years and time spans of up to billions of years. By contrast, Miley's condensed matter LENR transmutations occurred in a chemical cell with volume < one liter over two weeks at macroscopically moderate temperatures/pressures

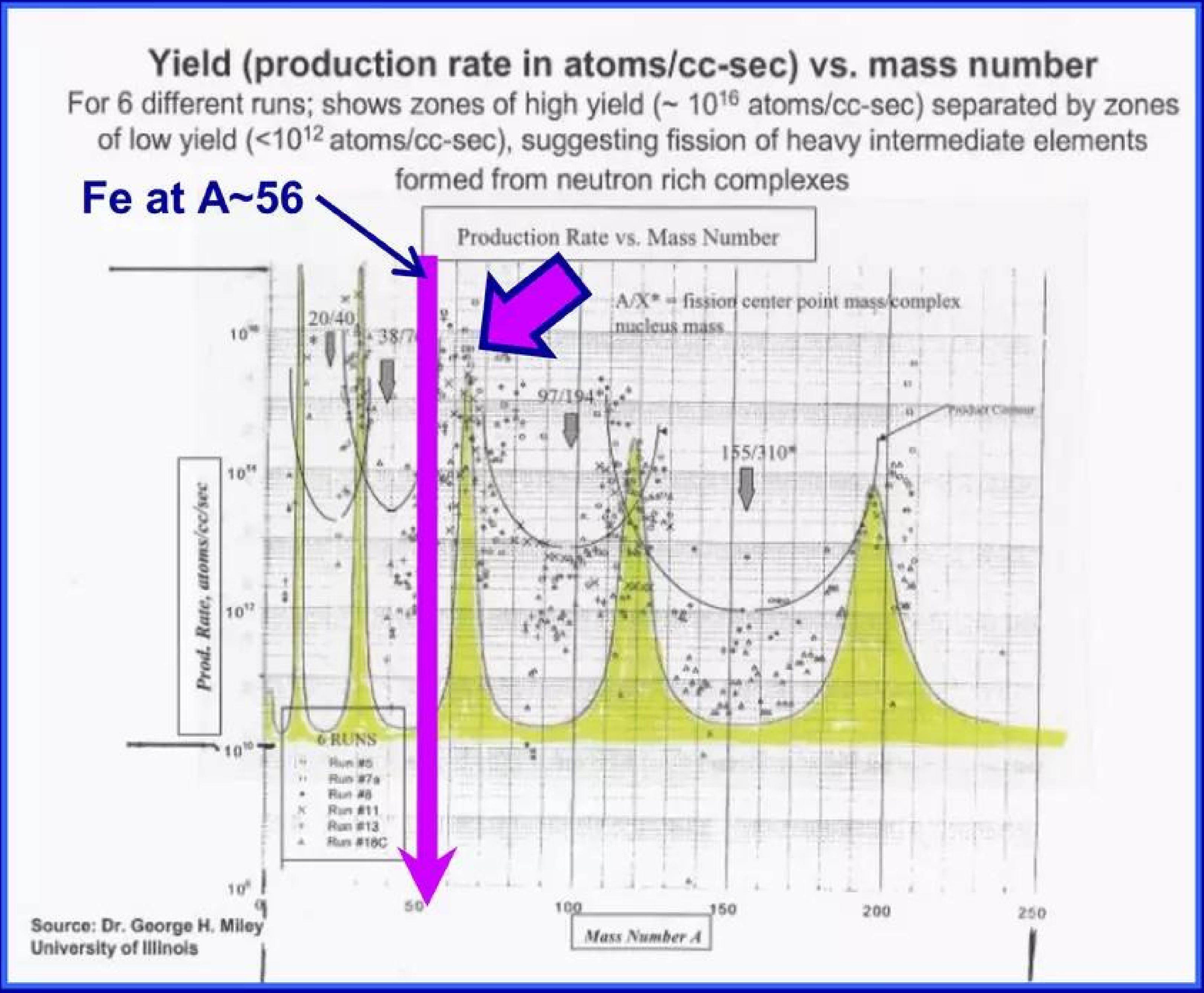
Peak Point #3: W-L optical model predicts that stable LENR transmutation products should strongly accumulate at approximately Mass # A ~ 63 - 66; this corresponds well to Miley condensed matter transmutation data ('fat' purple arrow below)

Solar elemental abundances vs. A



Solar abundance data *ca.* 1989 per Anders & Grevesse

LENR abundances in chemical cell


Yield (production rate in atoms/cc-sec) vs. mass number

For 6 different runs; shows zones of high yield (~ 10^{16} atoms/cc-sec) separated by zones of low yield ($<10^{12}$ atoms/cc-sec), suggesting fission of heavy intermediate elements formed from neutron rich complexes

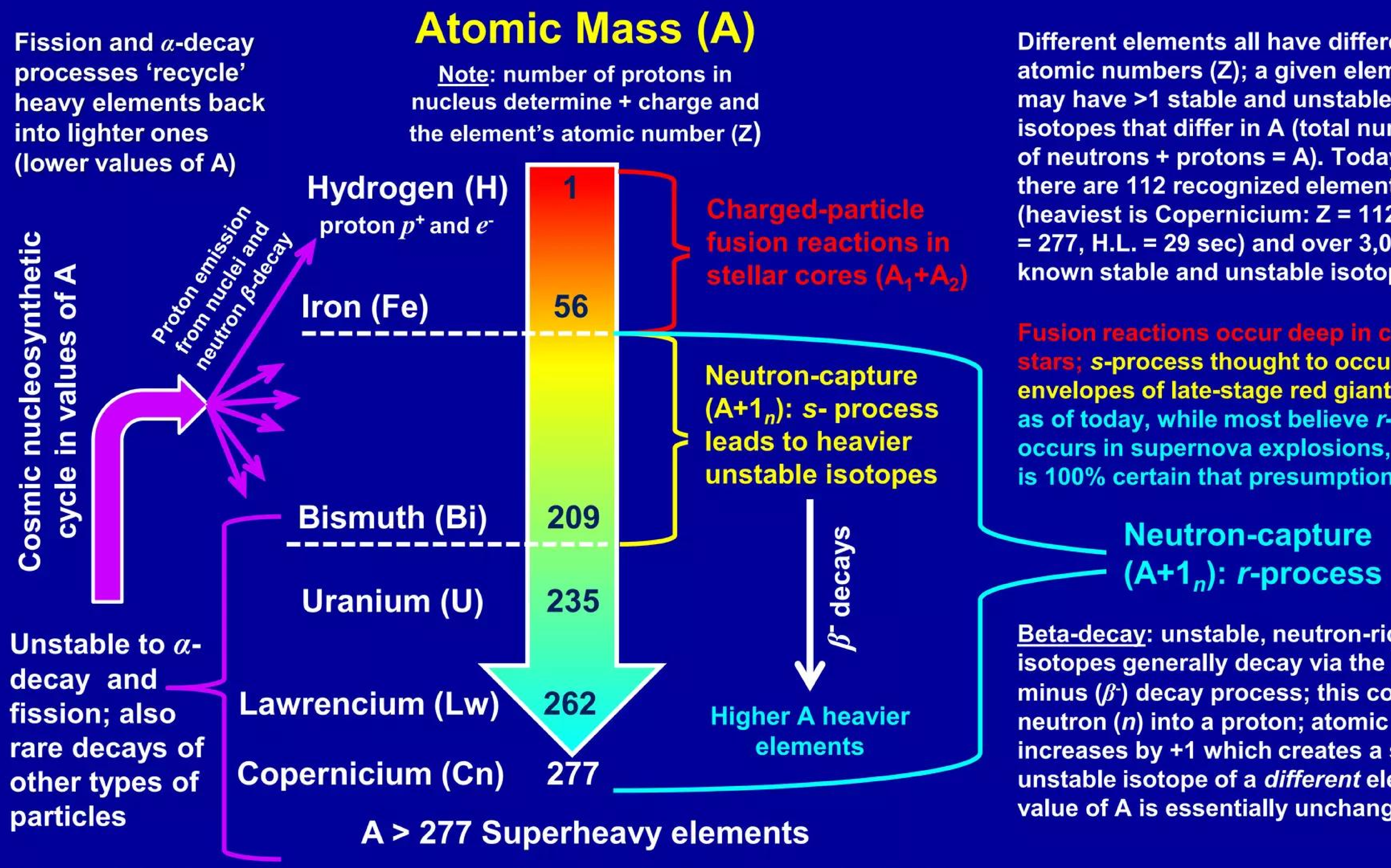
Source: Dr. George H. Miley
University of Illinois

W-L optical model superimposed on Miley's *ca.*1996 data

Powering the world to a green future

Astrophysicists claim stars create virtually all elements

Nucleosynthesis: fusion reactions (A=1-56) and s-/r-processes (A=57 and higher)



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

Cosmic nucleosynthetic cycle in values of A

Proton emission from nuclei and neutron β-decay

Unstable to α-decay and fission; also rare decays of other types of particles

Atomic Mass (A)

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

Hydrogen (H) proton p^+ and e^-	**1**
Iron (Fe)	**56**
Bismuth (Bi)	**209**
Uranium (U)	**235**
Lawrencium (Lw)	**262**
Copernicium (Cn)	**277**

A > 277 Superheavy elements

Charged-particle fusion reactions in stellar cores (A_1+A_2)

Neutron-capture ($A+1_n$): *s*- process leads to heavier unstable isotopes

β^- decays

Higher A heavier elements

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

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

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

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

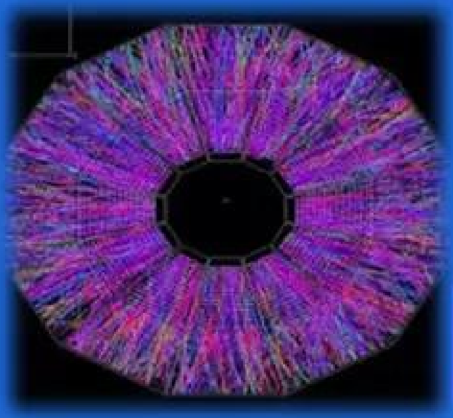
Powering the world to a green future

Astrophysicists claim stars create virtually all elements

W-L paradigm shift: LENR processes and stars <u>both</u> make contributions

Cosmic elemental nucleosynthetic cycle is Ouroboros of matter within our Universe

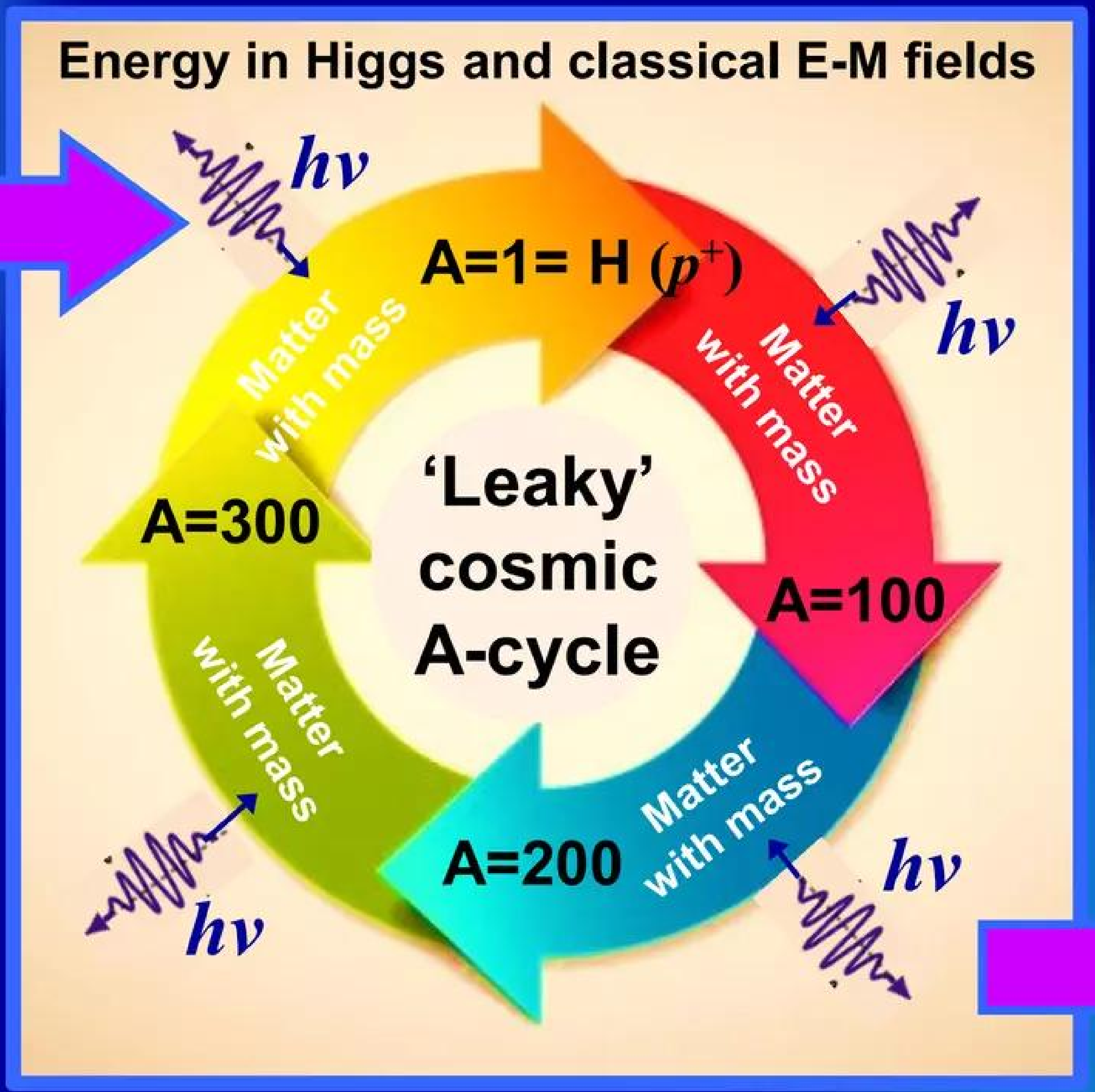
Input



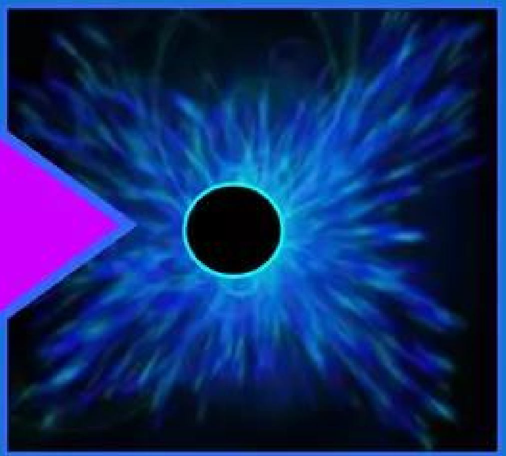
Big Bang

Universe = matter + energy

Matter cycles through values of A

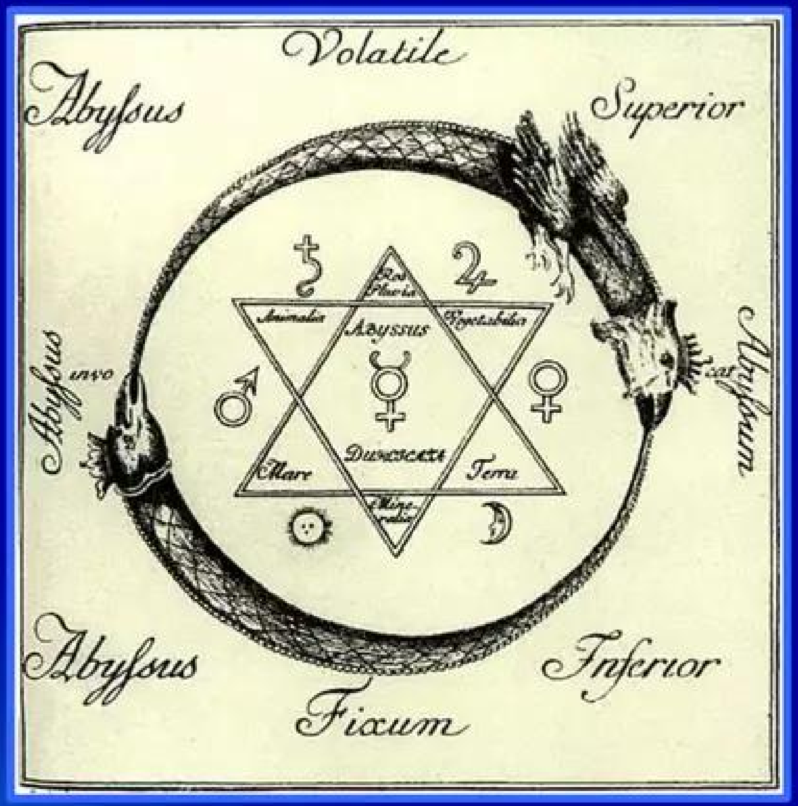


Output?



Black holes

Medieval alchemists' depiction of Ouroboros



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W-L paradigm shift: non-stellar nucleosynthesis

Radiation-free LENRs occur in condensed matter and stellar atmospheres

- ✓ **LENRs are an amazing neutron-catalyzed, hard radiation-free, star-like nucleosynthetic process that can operate at very significant rates in condensed matter at moderate macroscopic temperatures and under relatively low pressures**

- ✓ **LENRs' ex-core, neutron-catalyzed nucleosynthesis is similar to both the s- and r-process that astrophysicists believe are responsible for creating elements heavier than Iron (Fe, A=56); unlike the s-/r-processes, however, experiments show LENRs can also operate from A = 1 - 56, yet another paradigm shift**

- ✓ **Nucleosynthesis of elements in the Periodic Table is thus taking place way outside enormously hot stellar cores; this is a profound paradigm shift from what astrophysicists have heretofore believed was possible**

- ✓ **Non-stellar nucleosynthesis in otherwise comparatively benign physical environments is enabled by physics *aikido*, as we have explained herein**

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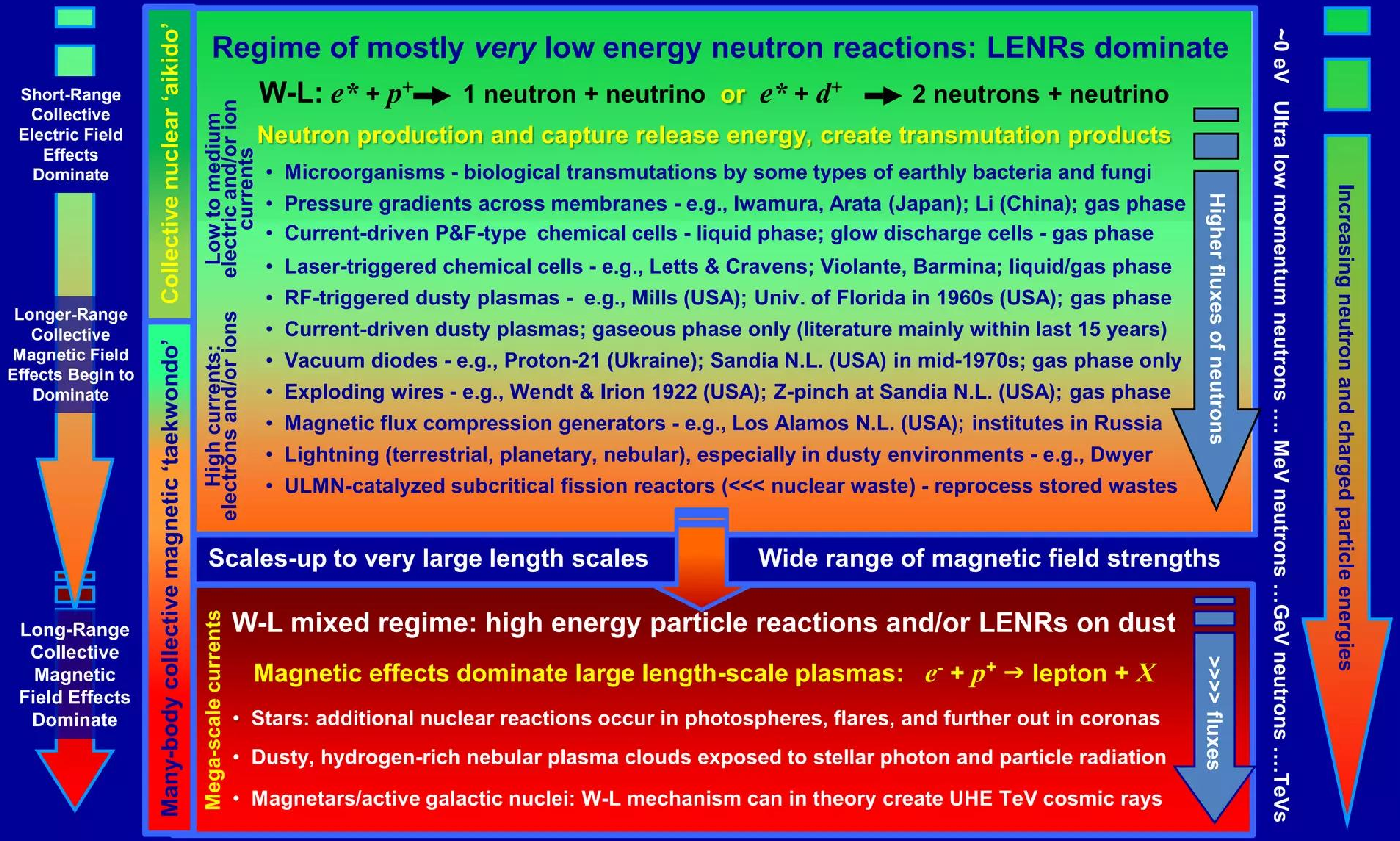
W-L paradigm shift: non-stellar nucleosynthesis



Short-Range Collective Electric Field Effects Dominate

Longer-Range Collective Magnetic Field Effects Begin to Dominate

Long-Range Collective Magnetic Field Effects Dominate

Collective nuclear 'aikido'

Many-body collective magnetic 'taekwondo'

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

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

Neutron production and capture release energy, create transmutation products

Low to medium electric and/or ion currents

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

High currents: electrons and/or ions

- RF-triggered dusty plasmas - e.g., Mills (USA); Univ. of Florida in 1960s (USA); gas phase
- Current-driven dusty plasmas; gaseous phase only (literature mainly within last 15 years)
- Vacuum diodes - e.g., Proton-21 (Ukraine); Sandia N.L. (USA) in mid-1970s; gas phase only
- Exploding wires - e.g., Wendt & Irion 1922 (USA); Z-pinch at Sandia N.L. (USA); gas phase
- Magnetic flux compression generators - e.g., Los Alamos N.L. (USA); institutes in Russia
- Lightning (terrestrial, planetary, nebular), especially in dusty environments - e.g., Dwyer
- ULMN-catalyzed subcritical fission reactors (<<< nuclear waste) - reprocess stored wastes

Higher fluxes of neutrons

Scales-up to very large length scales

Wide range of magnetic field strengths

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

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

Mega-scale currents

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

>>>> fluxes

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

Increasing neutron and charged particle energies

Powering the world to a green future

W-L paradigm shift: non-stellar nucleosynthesis

LENRs have been occurring in Earth's biosphere for many billions of years

- ✓ **Widom, Larsen & Srivastava have published a plausible many-body, collective magnetic mechanism whereby electroweak neutron production can occur in high-current atmospheric lightning discharges happening on Earth, as well as on other planets, moons and large hydrogen-rich regions of dusty nebulae subjected to large fluxes of energetic photon and particle radiation emitted by nearby stars**
- ✓ **This theoretical conjecture is well-supported by new experimental measurements of neutron production in lightning bolts that were published in *Physical Review Letters* by Gurevich *et al.* (2012). Such neutrons are invariably captured by gaseous elements in air --- mainly by Nitrogen and Oxygen atoms --- which will shift stable isotope ratios of N and O over geological time. W-L's predicted isotopic shifts are seen in NASA Genesis Mission data published by Burnett *et al.* in *PNAS* (2011)**
- ✓ **It is also well-known that lightning has been occurring in the earth's atmosphere since our planet condensed out of the pre-solar nebula about 4.5 x 10^9 years ago; neutron-catalyzed nucleosynthesis has therefore been occurring at low rates in Earth's atmosphere ever since**
- ✓ **Non-stellar production of elements could thus be occurring at widely varying rates in many more places around the Universe than any of us could have ever before imagined; this represents a paradigm shift in thinking about nucleosynthesis and the chemical evolution of planets and galaxies**

LENR transmutation processes may have been occurring at low rates in and around earth for >4.5 x 10^9 years

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W-L paradigm shift: non-stellar nucleosynthesis

LENRs occur in surprising numbers of natural and laboratory environments

Following URLs to Lattice SlideShare presentations provide many such examples; please see:

- ✓ **Catalytic converters of cars and trucks during normal vehicular operation**
  http://www.slideshare.net/lewisglarsen/lattice-energy-llc-len-rs-in-catalytic-convertersjune-25-2010
- ✓ **Ordinary atmospheric lightning discharges**
  http://www.slideshare.net/lewisglarsen/audio-larsenelectroweak-neutron-production-and-capture-in-lightning-dischargesans-san-diego-nov-14-2012
- ✓ **Industrial coking ovens during normal operation of pyrolysis processes (Slides #46 - 48)**
  http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewpahs-and-lenrsnov-25-2009
- ✓ **"Water trees" that can form spontaneously in XLPE electric power cables (Slides #49 - 54)**
  http://www.slideshare.net/lewisglarsen/cfakepathlattice-energy-llc-len-rs-in-liion-battery-firesjuly-16-2010
- ✓ **Compact fluorescent lights (CFLs) in which LENRs could potentially be occurring at low rates**
  http://www.slideshare.net/lewisglarsen/lattice-energy-llcare-lenrs-occurring-in-compact-fluorescent-lightsmarch-7-2013

Powering the world to a green future

Commercializing LENRs: cutting energy's Gordian Knot

Grand Collective Challenge for science, governments, and the private sector

> **"We choose to go to the Moon in this decade and do the other things, not because they are easy -**
> **but because they are hard.**
>
> **Because that challenge is one we are willing to accept,**
> **one we are unwilling to postpone and one we intend to win."**

U.S. President John F. Kennedy
Speech at Rice University (1962)

Powering the world to a green future

Commercializing LENRs: cutting energy's Gordian Knot

Grand Collective Challenge for science, governments, and the private sector

- ✓ Cost-effective, environmentally benign energy technologies are urgently needed. Vastly larger energy requirements of future societies must be satisfied at reasonable cost without destroying the entire planet in the process, whether by climate disasters or internecine wars over dwindling global supplies of oil. Successful commercialization and deployment of 'green' energy is imperative to attack an array of energy and climate change issues that confront our world today
- ✓ The Gordian Knot facing humanity is not that our world will ever run-out of energy *per se* in the foreseeable future. Between global coal reserves and electromagnetic energy in the form of photons streaming from the sun there is more than enough energy to be had for whatever purpose. Energy availability, in the broadest possible sense, is not the Gordian Knot. Rather, it is that worldwide consumers of energy need to have technologically usable, reasonably priced energy that is delivered to the right place at exactly the right time in forms that are environmentally benign and readily compatible with reasonable rates of sustainable, long-term global economic growth
- ✓ LENRs could be an important part of a diversified societal portfolio of 'green' carbon-free energy technologies. They have a unique combination of enormous energy density and cost advantages that cannot be matched by any other known nuclear or non-nuclear technology. If commercialized, these unparalleled attributes would enable LENRs to revolutionize both portable and distributed power generation, radically changing the world as it exists today. This could facilitate a new era of cost-effective, LENR-based all-electric or steam-powered vehicles with unprecedented performance and range capabilities that might finally end dominance of internal combustion engines in transportation
- ✓ Widespread global deployment of LENR technologies, together with synergistic large- and small-scale photovoltaic and wind-power systems, could create a less expensive, greener energy future for humanity. LENRs and the portfolio of 'green' carbon-free energy technologies have the potential to democratize access to affordable energy for every living inhabitant of the planet

Powering the world to a green future

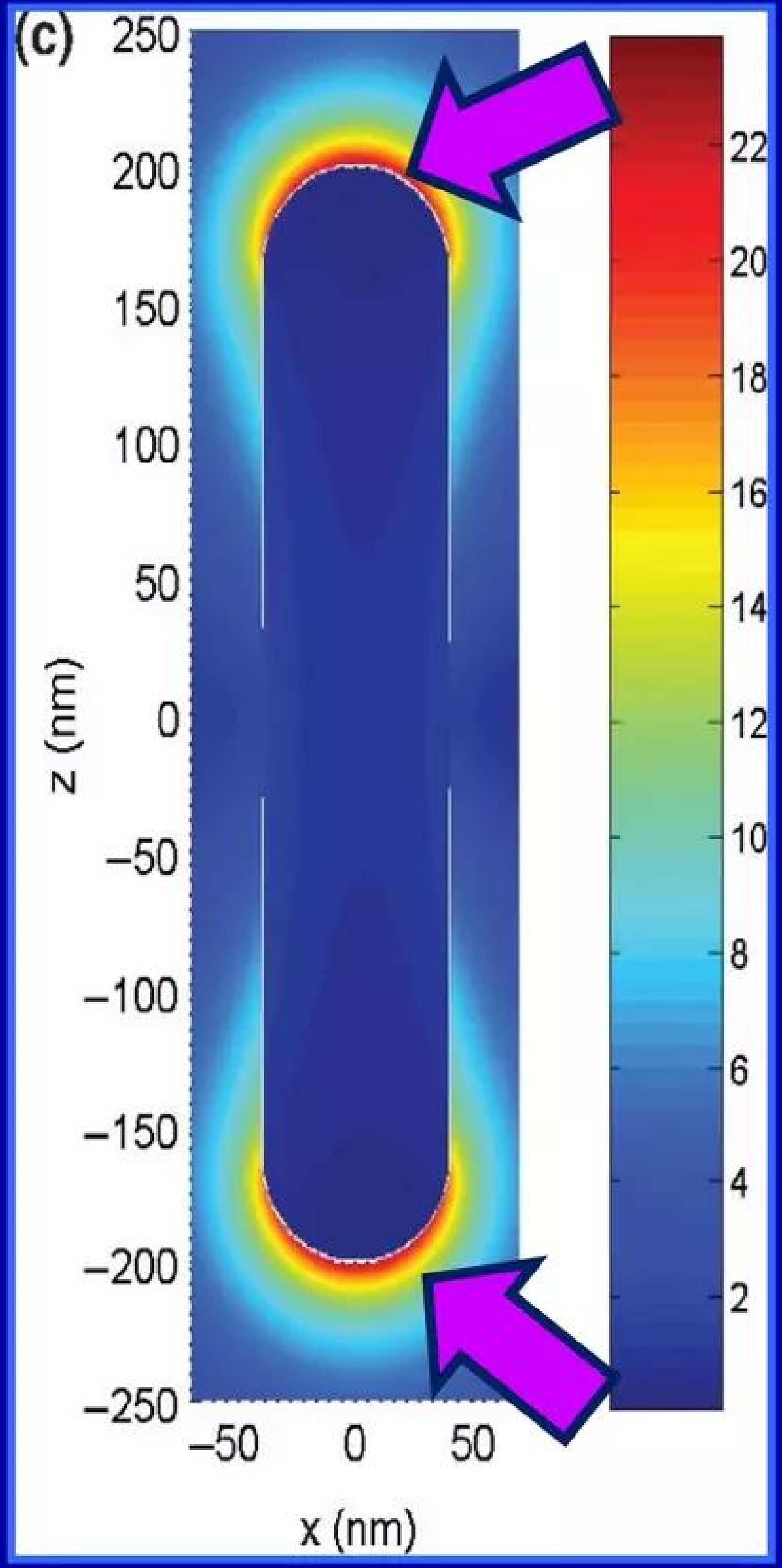
Commercializing LENRs: how do we get there from here?

Applied nanotechnology is needed to successfully commercialize LENRs

LENRs, plasmonics, and nanotechnology - joined at the hip:

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

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



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

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Commercializing LENRs: how do we get there from here?

Rates of LENRs can be increased substantially in non-natural environments

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

- ✓ Technologically, many-body collective electroweak neutron production rates can be manipulated by: (1) controlling total numbers and density of e^-p^+ pairs on a given surface (which is ~equivalent to controlling the area-density and dimensions of many-body, collectively oscillating surface 'patches' of protons or deuterons); and (2) controlling the rate and total quantity of appropriate form(s) of nonequilibrium energy input into LENR-active 'patches'; appropriate forms of input energy can go directly into high electric fields that 'bathe' SP electrons in a 'patch' --- it determines the number and effective masses of e^* electrons present in a given 'patch' whose increased masses are at values somewhere above the minimum mass-renormalization threshold ratio, β_0 that is required for initiating $e^* + p$ or $e^* + d$ electroweak reactions. The term $(\beta - \beta_0)^2$ in our published rate equation reflects the degree to which mass renormalized e^* electrons in a given 'patch' *exceed* the minimum threshold ratio for neutron production β_0. Details of this are explained in our first principles ULM neutron production rates calculation paper found on the Cornell arXiv at: http://arxiv.org/PS_cache/nucl-th/pdf/0608/0608059v2.pdf

- ✓ Maintain tight technological control over LENR reaction rates : all other things being equal, the higher the density of e^-p^+ reactants and the greater the rate and quantity of appropriate forms of nonequilibrium energy input, the higher the rate of ULM neutron production in μ-scale LENR-active 'patches' in an appropriately pre-configured condensed matter system

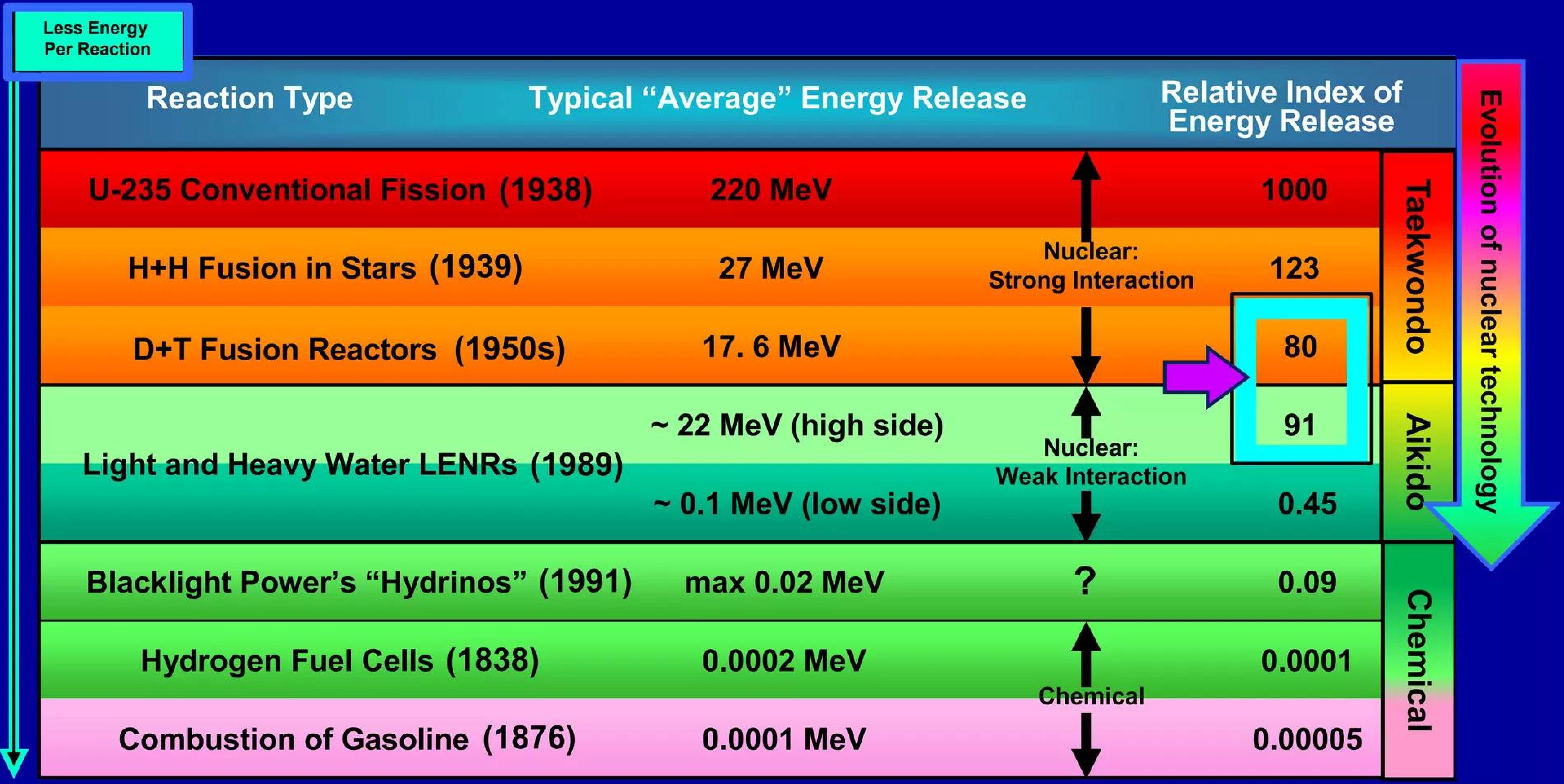
- ✓ LENR reaction rates can be very substantial in condensed matter systems: under exactly the right conditions and in a number of different types of experimental systems (e.g., rare *well-performing* current-driven aqueous H_2O/D_2O electrolytic chemical cells), rates of transmutation product production (which according to Widom-Larsen theory are very closely related to parallel rates of many-body, collective electroweak reaction ULM neutron production) can be quite substantial. Measured indirectly via qualitative and quantitative assays of LENR transmutation products, estimates of experimentally observed, effectively ULM neutron production rates reported by LENR researchers range from ~10^9 - 10^{10} cm^2/sec up to ~10^{12} - 10^{16} cm^2/sec in certain well-performing systems; this is high-enough to build ultra-performance thermal sources

Powering the world to a green future

LENR power generation competes with fusion processes

Chart below: LENRs' relative index of energy release overlaps fusion reactions

LENRs can release as much energy as D-T fusion without producing 'hard' radiation



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

Powering the world to a green future

LENR power generation competes with fusion processes

This fuel cycle has already been observed experimentally in condensed matter

LENR Lithium fuel cycle releases more energy than D-T fusion --- no 'hard' radiation

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

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

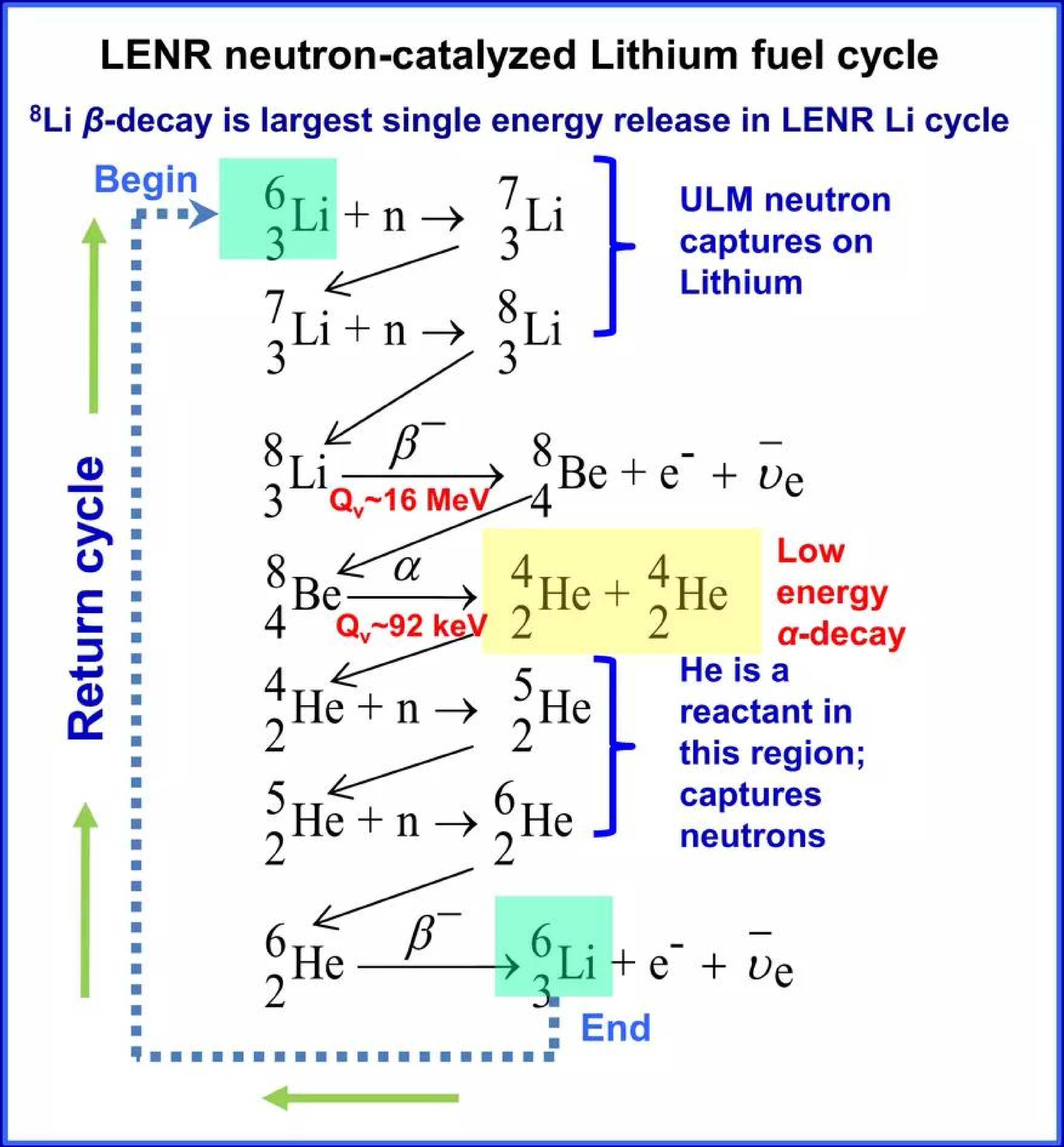
This particular cyclical LENR pathway can release about the same amount of energy as the D-T fusion reaction without creating any MeV-energy energetic neutrons, hard gamma radiation, or radioactive isotopes. Although a portion of the 26.9 MeV in excess nuclear binding energy released is lost ('haircut') 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:

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

ULMN-catalyzed LENR Lithium network cycle – from Eqs. 30 - 32



LENR neutron-catalyzed Lithium fuel cycle

^{8}Li β-decay is largest single energy release in LENR Li cycle

$$^{6}_{3}\mathrm{Li} + n \rightarrow {}^{7}_{3}\mathrm{Li}$$

$$^{7}_{3}\mathrm{Li} + n \rightarrow {}^{8}_{3}\mathrm{Li}$$

$$^{8}_{3}\mathrm{Li} \xrightarrow[Q_v\sim16\ \mathrm{MeV}]{\beta^-} {}^{8}_{4}\mathrm{Be} + e^- + \bar{\nu}_e$$

$$^{8}_{4}\mathrm{Be} \xrightarrow[Q_v\sim92\ \mathrm{keV}]{\alpha} {}^{4}_{2}\mathrm{He} + {}^{4}_{2}\mathrm{He}$$

$$^{4}_{2}\mathrm{He} + n \rightarrow {}^{5}_{2}\mathrm{He}$$

$$^{5}_{2}\mathrm{He} + n \rightarrow {}^{6}_{2}\mathrm{He}$$

$$^{6}_{2}\mathrm{He} \xrightarrow{\beta^-} {}^{6}_{3}\mathrm{Li} + e^- + \bar{\nu}_e$$

Powering the world to a green future

Paradigm shift: safe portable nuclear power systems

LENRs huge energy density allows potent power sources to be ultra-compact

- ✓ To simplify calculations, we will assume that conversion of input energy (in this case, an electric current) into energy available to produce LENR ULM neutrons is 100 percent efficient in order to estimate a *theoretical upper bound* on potential energy releases from a compact LENR heat source; will also assume that 100 percent of the ULM neutrons produced in the hypothetical device are absorbed locally (a pretty safe bet that is supported by 20+ years of experiments) and that they are *only* absorbed by a 'target fuel' comprising isotopically pure Lithium-6, resulting in a series of nuclear reactions beginning with Lithium-6 and ending with Helium-4 (please see discussion on Slide #92). Lastly, we will assume that the 'base fuel' used to produce LENR ULM neutrons in our hypothetical device is *deuterium* and that it has an LENR-active working surface area of 1 cm^2

- ✓ Input energy required to produce 1 neutron/cm^2/sec from deuterium 'base fuel' to react with the Lithium-6 'target fuel' is 0.39 MeV per neutron. However, we need two ULM neutrons to complete the entire series of reactions, so the required total input energy to the device is 0.78 MeV/cm^2/sec. The net energy release from that particular series of LENR reactions starting with Lithium-6 is 26.9 MeV/cm2/sec = 4.28 x 10^{-12} J/cm^2/sec (1 eV = 1.602 x 10^{-19} J); 26.9 MeV thus represents a theoretical upper bound of ~ 34x total input power

- ✓ As there are ~ 10^{14} of these 26.9 MeV energy releases taking place per second on the 1 cm^2 LENR device, the total energy release is 4.28 x 10^{-12} J/cm^2/sec x 10^{14} = 428 J/cm^2/sec. This represents 428 W/cm^2, a large device-level power density. At a lesser ULM neutron production rate of 1 x 10^{12} cm^2/sec, the overall energy production rate would drop down to 4.28 J/cm^2/sec or 4.28 W/cm^2. At a ULM neutron production rate of 1 x 10^{11} cm^2/sec, the energy production rate would drop down to 0.428 J/cm^2/sec or 0.428 W/cm^2, which is close to levels of excess heat output that are often observed in the *limited subset* of electrolytic LENR experiments that researchers deem 'successful' at making excess heat

- ✓ In this particular example, a heat generating rate of 428 W/cm^2 means 0.428 kWh/cm^2 produced in an hour for a Lithium-6-fueled 1 cm^2 LENR device, without releasing any CO_2. In comparison to the minuscule total mass of LENR reactants, the complete combustion of 1 US gallon of gasoline (weighing 2.7 kg) generates ~33.56 kWh of heat energy and releases ~8.8 kg of CO_2 into the atmosphere. Scaling up the surface area of the idealized LENR device 1,000 fold would give a 428 kW power source, while a 1 m^2 device would provide a much higher-output 4.28 Megawatt power source

Powering the world to a green future

Paradigm shift: safe portable nuclear power systems

LENRs could eventually compete directly with chemical batteries and fuel cells

LENRs Versus Chemical Energy Sources: Batteries, Fuel Cells, and Microgenerators

Source of Energy	Approximate Energy Density (Watt*hours/kg)	
Alkaline Battery	164	Chemical
Lithium Battery	329	
Zinc-Air Battery	460	
Direct Methanol Fuel Cell (35% efficient)	1,680	
Gas Burning Microgenerator (20% efficient)	2,300	
100% Efficient Combustion of Pure Methanol	5,930	
100% Efficient Combustion of Pure Gasoline	11,500	
LENRs (based on an assumption of an average of 0.5 MeV per nuclear reaction in an LENR system)	**57,500,000** (maximum theoretical energy density – only a fraction would be achievable in practice)	Aikido

Powering the world to a green future

Paradigm shift: safe portable nuclear power systems

Energy density: key advantage in portable, small-scale, and mobile power

Solar and wind have innately low energy densities - need to collect and concentrate it

- ✓ **Vast majority of vehicles are now powered by internal combustion engines burning gasoline or diesel fuels with O_2 because effective energy densities are much higher than all-electric vehicles powered by advanced chemical batteries**
- ✓ **At the present time, vehicles with internal combustion engines have substantially lower total lifetime $ costs than all-electric vehicles**
- ✓ **LENRs are at least 5,000 times more energy-dense than gasoline**
- ✓ **If LENRs can be scaled-up to power vehicles, have opportunity to displace internal combustion**

Petroleum energy density: "A single gallon of gasoline contains approximately forty megajoules of chemical energy. Dividing energy by volume yields an energy density of ten billion joules per cubic meter. Gasoline is ten quadrillion times more energy-dense than solar radiation and one billion times more energy-dense than wind and water power."

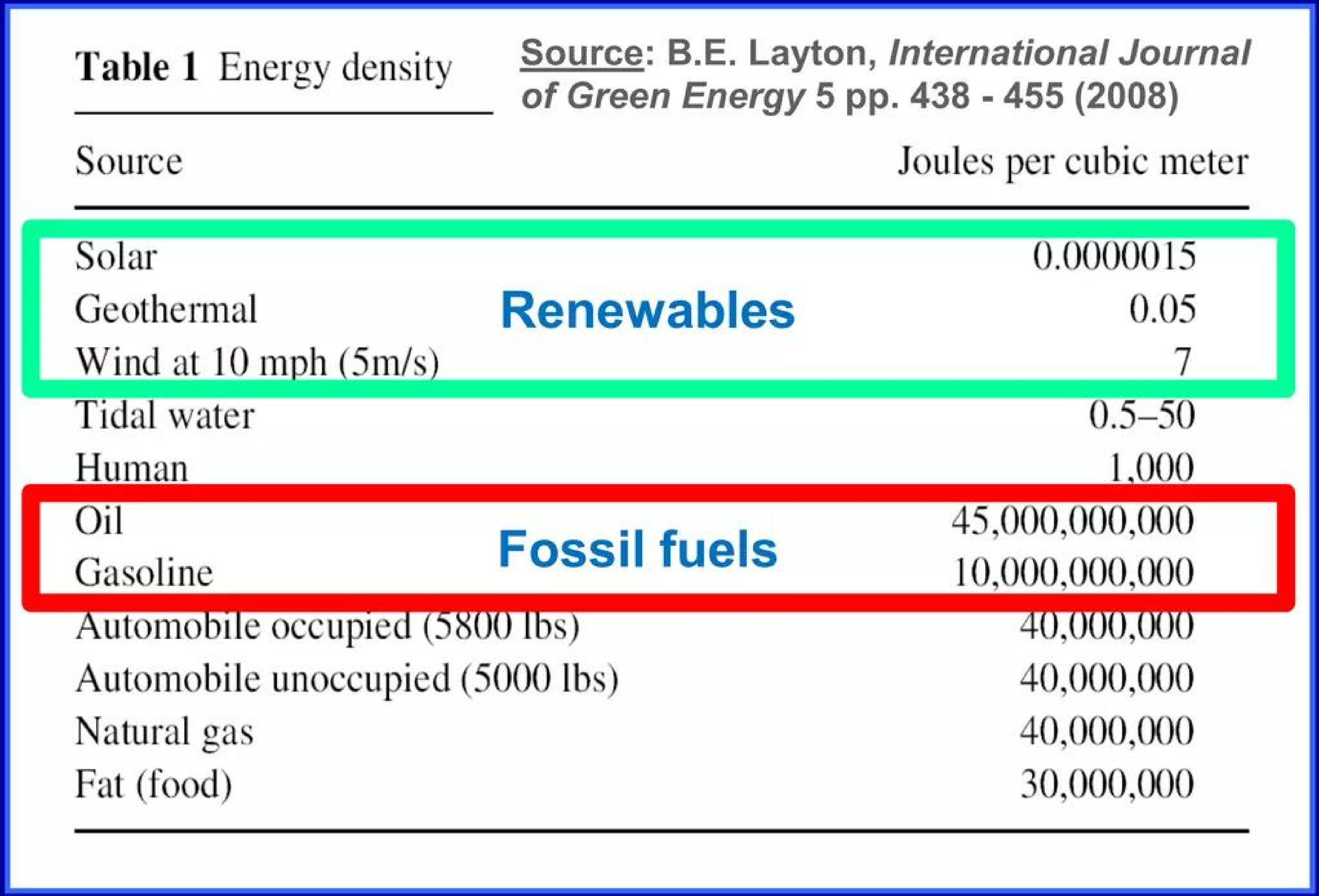


Table 1 Energy density

Source: B.E. Layton, *International Journal of Green Energy* 5 pp. 438 - 455 (2008)

Source	Joules per cubic meter
Solar	0.0000015
Geothermal	0.05
Wind at 10 mph (5m/s)	7
Tidal water	0.5–50
Human	1,000
Oil	45,000,000,000
Gasoline	10,000,000,000
Automobile occupied (5800 lbs)	40,000,000
Automobile unoccupied (5000 lbs)	40,000,000
Natural gas	40,000,000
Fat (food)	30,000,000

Renewables

Fossil fuels

Source: http://www.drexel.edu/~/media/Files/greatworks/pdf_sum10/WK8_Layton_EnergyDensities.ash

Powering the world to a green future

Paradigm shift: safe portable nuclear power systems

LENRs could eventually compete directly with chemical batteries and fuel cells

- ✓ **Advanced batteries are just beginning to approach their technological limits in terms of achievable energy densities; >100x increase in energy density is not possible chemically**
- ✓ **Lithium-ion batteries could unknowingly be encountering LENRs already; subset of "field failure" thermal runaways could potentially be triggered by rare LENR 'hotspots' inside batteries**
- ✓ **Lithium-ion batteries effectively store electrical energy in electrons in ions at only eV energies; a LENR Lithium fuel cycle releases ~27 MeV per nuclear reaction cycle (~27 *million* x more)**
- ✓ **Since they are radiation-free and do not produce long-lived radioactive isotopes, battery-like LENR power generation devices would not require any radiation shielding or containment subsystems, dramatically reducing their weight, size, and cost; enable development of revolutionary portable nuclear systems**
- ✓ **With energy densities >1 million x those of chemical systems, compact, portable LENR-based generators could eventually compete directly with batteries and fuel cells in key applications**

? perhaps in some thermal runaways

Powering the world to a green future

Market applications for commercial LENR technology

Inherent scalability of total power output could address many market needs

Time

Applications	Description	Target Markets
LENRs enable safe, 'green' carbon-free nuclear energy production and power generation at reasonable cost - Vastly greater energy densities and longevity at a lower price per kWh compared to chemical power sources	Scale-up and integrate LENR heat sources w. different energy conversion technologies: e.g., develop portable battery-like devices using thermoelectrics that can convert raw heat directly to DC electricity; or, use heat to rotate a shaft for propulsion (e.g., Stirling or modern steam engines in motor vehicles)	SAFE - no radiation shielding or nuclear waste issues; could also eventually enter portable power markets and compete directly against chemical batteries, small fuel cells, and microgenerators
Bitumen extraction, heavy oil recovery, and/or oil shale processing According to Prof. K. Deffeyes of Princeton University, about 2/3 of oil remaining in the ground worldwide is classified as 'heavy'	Use well-hole LENR thermal sources to heat-up bitumen or heavy oil underground: reduce production costs, enhance recovery; could use LENR heaters for *in-situ* underground upgrading and downstream process heat	Major benefit to large oil producers – can help increase long-term supplies of oil and reduce total production costs as well as CO_2 'footprint'
Develop much cleaner fission power generation technologies Use LENRs and ultra low momentum neutrons (ULMs) for triggering fission	Design new types of LENR-based subcritical fission reactors that can burn existing fissionable fuels down to stable isotopes – little or no long-lived radioactive wastes	Retrofit new ULM-neutron reactors into existing nuclear fission power systems; much better safety and lower costs
Nuclear waste treatment Transmute dangerous radioactive nuclear waste using LENRs; generate additional power from waste burn-up	Develop turnkey systems for on-site nuclear waste clean-up of existing worldwide inventories of stored fission wastes from nuclear power plants	Nuclear waste remediation and clean-up – opportunities in many countries, e.g., US, France, Japan, China, etc.
Transmutation of stable elements Produce almost any very valuable element or isotope in the periodic table at competitive costs compared to present mining and refining operations	Use LENRs to transmute less expensive elements into much more valuable ones – first do it abiologically; later migrate to methods using various species of genetically engineered bacteria	Mostly target precious and rare metals production, e.g., platinum, gold, rhodium, rare earth elements, etc

First targets

Potential long-term opportunities

Powering the world to a green future

Oil and LENRs are surprisingly synergistic over near-term

Potential to reduce production costs and increase revenues from oil sands

- ✓ Synthetic crude oil produced from bitumen presently accounts for a substantial portion of Canada's total oil production. However, compared to conventional oil (obtained from traditional, easily accessible, low-production-cost petroleum producers such as Saudi Arabia, Iraq, and Iran), synthetic crude created from viscous bitumen is now significantly more expensive and complicated to produce using today's best available extraction and processing technologies

- ✓ Elaborating, whether surface-mined or extracted through well-holes, in Canada natural gas is presently being burned to make steam which is used to heat bitumen-containing sands so liquid oil can flow out of pores between rock particles. To eliminate burning of natural gas for making steam, high performance, cost-effective LENR-based nuclear heaters with duty cycles of 5,000 - 10,000 hours between scheduled refueling/maintenance breaks could potentially be developed and mass produced

- ✓ High-performance LENR heat sources would be small enough to be lowered down existing well-holes to reach desired locations in oil-bearing formations where long-lived, controllable generation of intense heat is required for economically attractive recovery % and perhaps even *in-situ* upgrading to middle distillates. LENRs could thus reduce extraction and production costs, as well as reduce the total 'carbon footprint' of the Canadian bitumen 'mining' industry as it exists today

- ✓ As Lattice has shown in other published technical documents, it is possible that polycyclic aromatic hydrocarbon (PAH) aromatic fractions in bitumen and other heavy oils could someday be separately extracted and then specially processed to be 'burned' directly as 'green' nuclear fuels. Incredibly, presently troublesome PAHs could potentially be worth perhaps greater than a million times more $$$ in BTU equivalents when utilized as an LENR fuel, as compared to alternatively being 'ring-cracked' and combusted with Oxygen in vehicle engines or simply used as a chemical process feedstock

Powering the world to a green future

Coal and LENRs are also surprisingly synergistic

In theory, coal might also be processed to yield ‘green’ CO_2-free LENR fuels

See Lattice document dated March 15, 2012:

http://www.slideshare.net/lewisglarsen/lattice-energy-llccoal-as-a-clenr-co2-emissionless-fuelmarch-15-2012-12109180

- ✓ **Coal of all kinds is innately chock-full of aromatic carbon rings of one kind or another; in the above noted Lattice document, we discuss how $_6C^{12}$ ‘seed’ LENR networks exist and have been observed in laboratory experiments. That being the case, the presence of aromatic rings in the molecular structure of coal implies that there may be a potential commercial opportunity for coal to be specially processed to yield $_6C^{12}$ ‘seed’ LENR fuels**

- ✓ **Please note that at today’s modern coal-fired power plants, bulk coal from one or more origins is delivered to the facility via ship, barge, or rail, for local storage prior to its use. Before being injected into coal-fired boilers, macro-sized chunks of coal must be mechanically broken-up into much smaller particles by a machine called a coal pulverizer. Optimum burnable sizes of coal particles vary by boiler type; the smallest today get down to ‘average’ diameters on the order or “200 mesh” or ~74 μm (microns)**

- ✓ **However, present smallest coal particle sizes of 74 *µm* in diameter *(*74,000 nanometers - *nm*) are just too large and wasteful for practical use as feedstock for further chemical processing that will produce usable $_6C^{12}$ LENR fuels; first step in creating new coal-based LENR fuels is to use a second-stage fracturing process that further reduces average coal particle sizes by >10x, i.e., down to no more than ~7 - 8 µm ; preferably smaller, if possible**

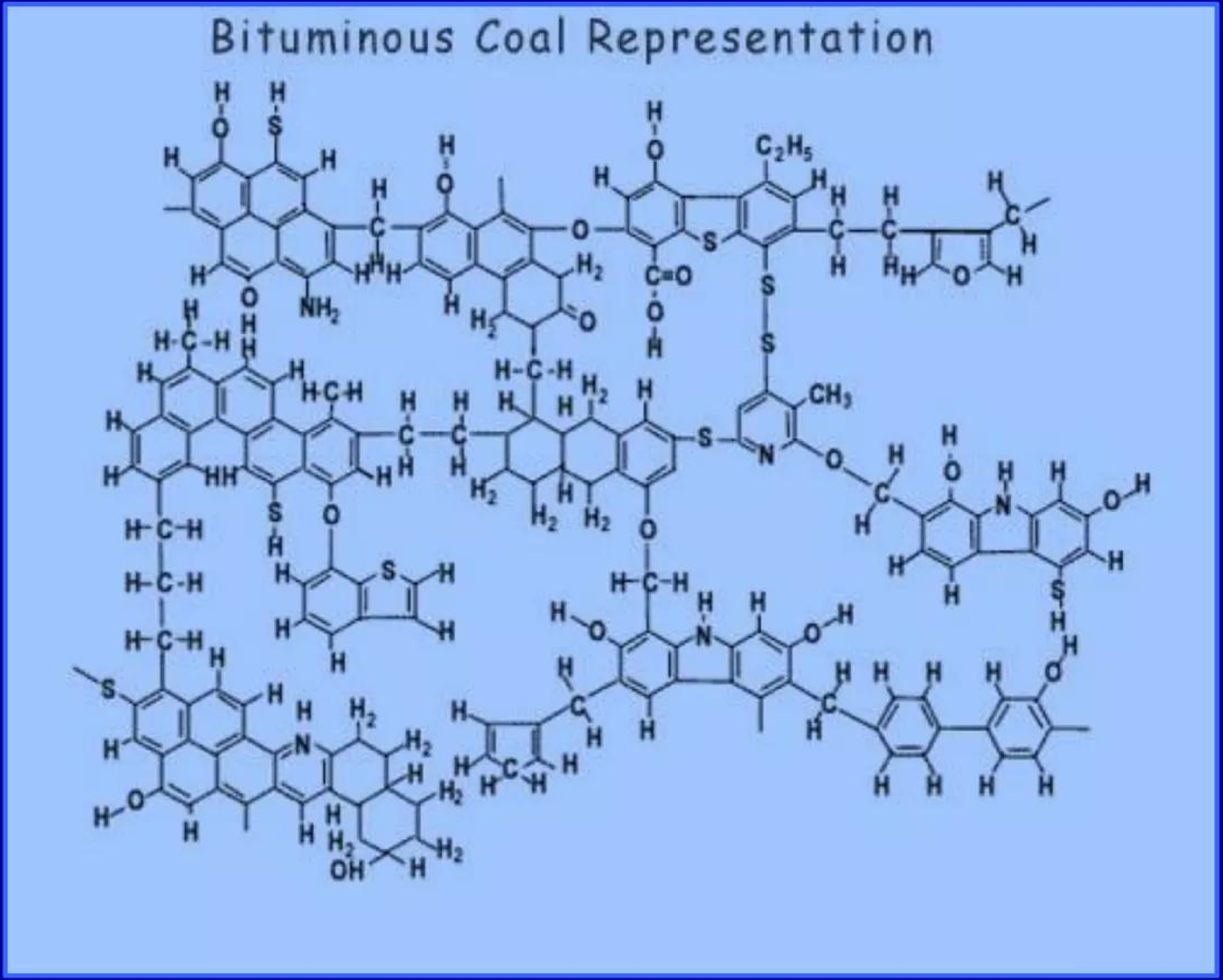
Powering the world to a green future

Coal and LENRs are also surprisingly synergistic

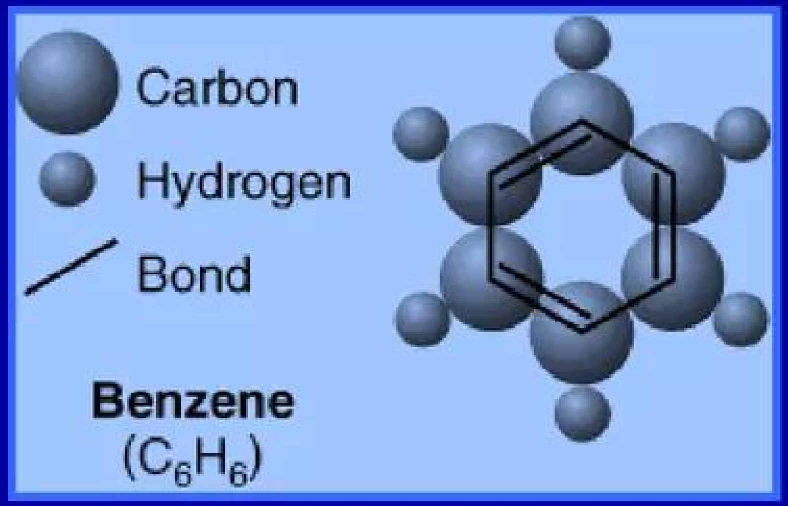
In theory, coal might also be processed to yield a 'green' CO_2-free LENR fuel

Molecular structures: coal shown left; benzene (aromatic) ring and PAHs to right

Bituminous coal's very complex structure:



Benzene:



PAH:

Unsaturated Phenanthrene $C_{14}H_{10}$

Powering the world to a green future

LENR transmutation of Carbon releases substantial energy

In theory, heavy oil and coal might be processed to also yield 'green' LENR fuel

Instead of burning Carbon with Oxygen, simply transmute it into other elements

- ✓ **What we will refer to as 'seed' or 'target' nuclei are simply stable elements (which are themselves initially comprised of some number of natural isotopes) that serve as initial starting points for complex, dynamic neutron-capture-driven LENR transmutation reaction networks**

- ✓ **What engineers call a "fuel cycle" in the nuclear power industry is essentially the same as what we call an LENR network. Major difference is that there are only very limited number of fuel cycles used in today's commercial fission reactors and they are based on Uranium isotopes (less problematic Thorium fuels are still under development). By contrast, the possibilities for LENR fuel cycles are almost limitless --- literally *any* 'seed' element that will capture neutrons might be used (but some are much better than others; please see Lithium example herein)**

- ✓ **We will now show a segment of a hypothetical Carbon-seed LENR network that might be commercially usable at some point in the future if presently troublesome aromatics found naturally in oil and coal can be processed into nanoparticulate forms in which LENRs can be triggered. In Lattice's new scheme, carbon atoms present in oil and coal would be <u>transmuted</u> rather than oxidized**

Powering the world to a green future

LENR transmutation of Carbon releases substantial energy

In theory, heavy oil and coal might be processed to also yield 'green' LENR fuel

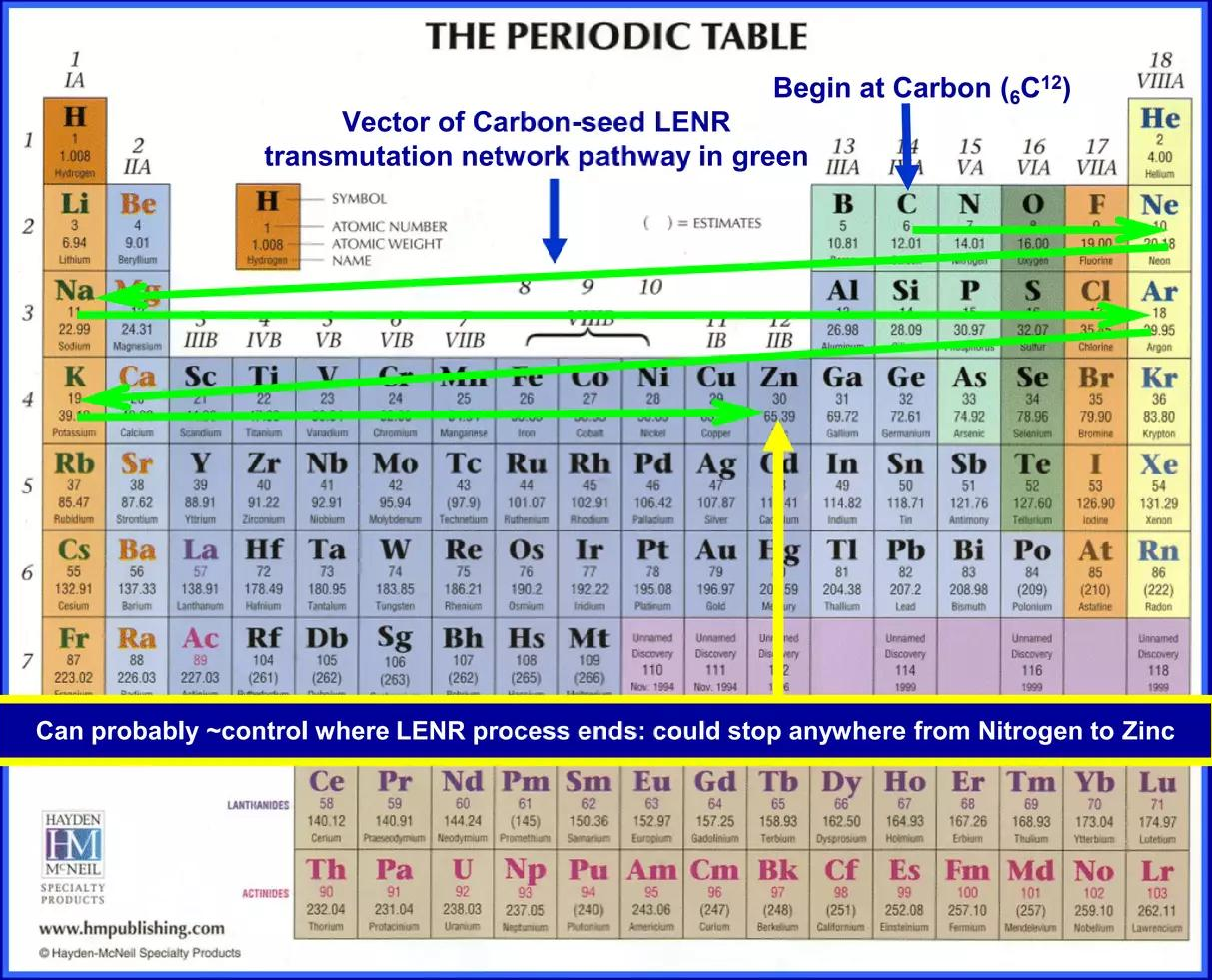
Carbon atoms in aromatic rings provide starting point for 'green' transmutation process

Combustion:

Combustion of Carbon atoms in fossil fuels with Oxygen O_2 produces CO_2 and H_2O; CO_2 gas emissions are a problem, which has led to schemes like Carbon capture and sequestration (CCT)

Additional issues with coal's varied trace elements

Scale of energy release from chemical reaction combustion processes are on the order of eVs



Begin at Carbon ($_6C^{12}$)

Vector of Carbon-seed LENR transmutation network pathway in green

Can probably ~control where LENR process ends: could stop anywhere from Nitrogen to Zinc

Transmutation:

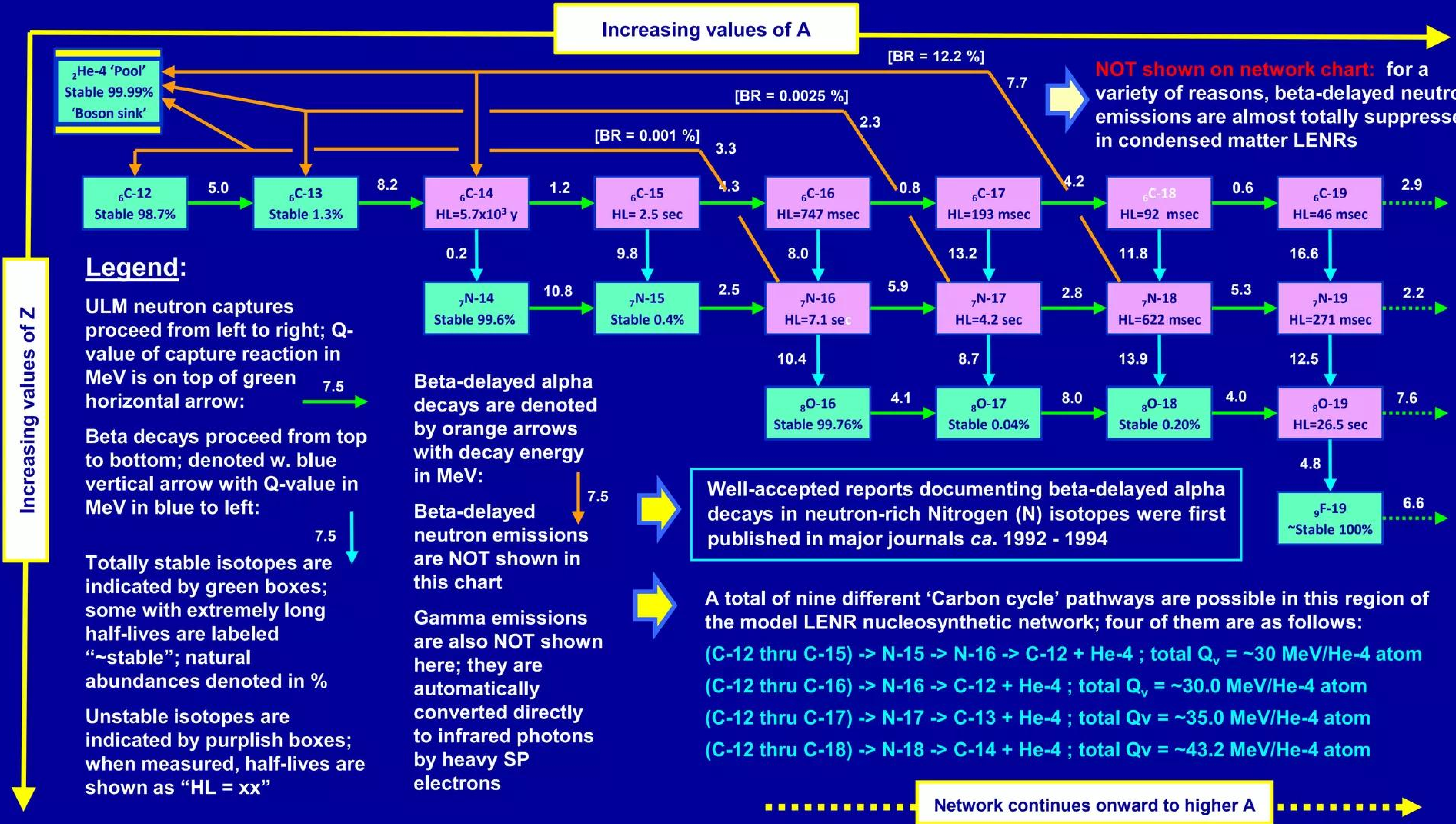
Depending on where nuclear process was stopped, LENR transmutation of Carbon atoms in oil and coal could produce a wide variety of stable elements up through Zinc; gaseous emissions might be limited to Neon, Argon, Nitrogen and/or preferably Oxygen

Scale of energy release is in MeV; or $>10^6$ larger than chemical reactions

Powering the world to a green future

LENR transmutation of Carbon releases substantial energy

Carbon (C) atoms transmuted into Nitrogen (N), Oxygen (O), and Fluorine (F)



NOT shown on network chart: for a variety of reasons, beta-delayed neutron emissions are almost totally suppressed in condensed matter LENRs

Legend:

ULM neutron captures proceed from left to right; Q-value of capture reaction in MeV is on top of green horizontal arrow:

Beta decays proceed from top to bottom; denoted w. blue vertical arrow with Q-value in MeV in blue to left:

Totally stable isotopes are indicated by green boxes; some with extremely long half-lives are labeled "~stable"; natural abundances denoted in %

Unstable isotopes are indicated by purplish boxes; when measured, half-lives are shown as "HL = xx"

Beta-delayed alpha decays are denoted by orange arrows with decay energy in MeV:

Beta-delayed neutron emissions are NOT shown in this chart

Gamma emissions are also NOT shown here; they are automatically converted directly to infrared photons by heavy SP electrons

Well-accepted reports documenting beta-delayed alpha decays in neutron-rich Nitrogen (N) isotopes were first published in major journals *ca.* 1992 - 1994

A total of nine different 'Carbon cycle' pathways are possible in this region of the model LENR nucleosynthetic network; four of them are as follows:

(C-12 thru C-15) -> N-15 -> N-16 -> C-12 + He-4 ; total Q_v = ~30 MeV/He-4 atom

(C-12 thru C-16) -> N-16 -> C-12 + He-4 ; total Q_v = ~30.0 MeV/He-4 atom

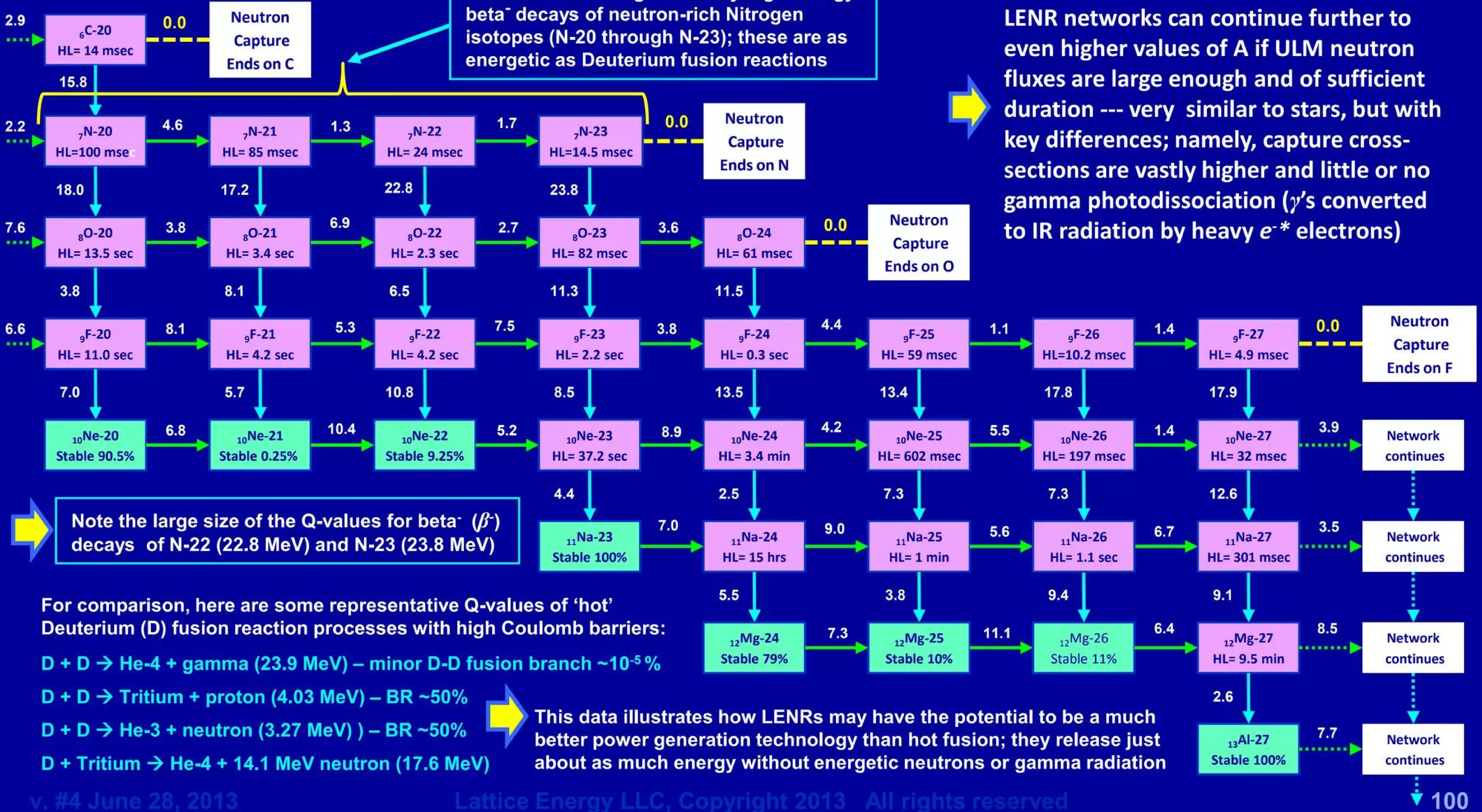
(C-12 thru C-17) -> N-17 -> C-13 + He-4 ; total Qv = ~35.0 MeV/He-4 atom

(C-12 thru C-18) -> N-18 -> C-14 + He-4 ; total Qv = ~43.2 MeV/He-4 atom

Powering the world to a green future

LENR transmutation of Carbon releases substantial energy

Carbon-seed LENR network can produce progressively heavier elements



Please note this region of very high-energy beta$^-$ decays of neutron-rich Nitrogen isotopes (N-20 through N-23); these are as energetic as Deuterium fusion reactions

2.9 → $_{6}$C-20 HL= 14 msec — 0.0 — Neutron Capture Ends on C

15.8

2.2 → $_{7}$N-20 HL=100 msec → 4.6 → $_{7}$N-21 HL= 85 msec → 1.3 → $_{7}$N-22 HL= 24 msec → 1.7 → $_{7}$N-23 HL=14.5 msec — 0.0 — Neutron Capture Ends on N

18.0 | 17.2 | 22.8 | 23.8

7.6 → $_{8}$O-20 HL= 13.5 sec → 3.8 → $_{8}$O-21 HL= 3.4 sec → 6.9 → $_{8}$O-22 HL= 2.3 sec → 2.7 → $_{8}$O-23 HL= 82 msec → 3.6 → $_{8}$O-24 HL= 61 msec — 0.0 — Neutron Capture Ends on O

3.8 | 8.1 | 6.5 | 11.3 | 11.5

6.6 → $_{9}$F-20 HL= 11.0 sec → 8.1 → $_{9}$F-21 HL= 4.2 sec → 5.3 → $_{9}$F-22 HL= 4.2 sec → 7.5 → $_{9}$F-23 HL= 2.2 sec → 3.8 → $_{9}$F-24 HL= 0.3 sec → 4.4 → $_{9}$F-25 HL= 59 msec → 1.1 → $_{9}$F-26 HL=10.2 msec → 1.4 → $_{9}$F-27 HL= 4.9 msec — 0.0 — Neutron Capture Ends on F

7.0 | 5.7 | 10.8 | 8.5 | 13.5 | 13.4 | 17.8 | 17.9

$_{10}$Ne-20 Stable 90.5% → 6.8 → $_{10}$Ne-21 Stable 0.25% → 10.4 → $_{10}$Ne-22 Stable 9.25% → 5.2 → $_{10}$Ne-23 HL= 37.2 sec → 8.9 → $_{10}$Ne-24 HL= 3.4 min → 4.2 → $_{10}$Ne-25 HL= 602 msec → 5.5 → $_{10}$Ne-26 HL= 197 msec → 1.4 → $_{10}$Ne-27 HL= 32 msec → 3.9 → Network continues

4.4 | 2.5 | 7.3 | 7.3 | 12.6

$_{11}$Na-23 Stable 100% → 7.0 → $_{11}$Na-24 HL= 15 hrs → 9.0 → $_{11}$Na-25 HL= 1 min → 5.6 → $_{11}$Na-26 HL= 1.1 sec → 6.7 → $_{11}$Na-27 HL= 301 msec → 3.5 → Network continues

5.5 | 3.8 | 9.4 | 9.1

$_{12}$Mg-24 Stable 79% → 7.3 → $_{12}$Mg-25 Stable 10% → 11.1 → $_{12}$Mg-26 Stable 11% → 6.4 → $_{12}$Mg-27 HL= 9.5 min → 8.5 → Network continues

2.6

$_{13}$Al-27 Stable 100% → 7.7 → Network continues

LENR networks can continue further to even higher values of A if ULM neutron fluxes are large enough and of sufficient duration --- very similar to stars, but with key differences; namely, capture cross-sections are vastly higher and little or no gamma photodissociation (γ's converted to IR radiation by heavy e^-* electrons)

Note the large size of the Q-values for beta$^-$ (β^-) decays of N-22 (22.8 MeV) and N-23 (23.8 MeV)

For comparison, here are some representative Q-values of 'hot' Deuterium (D) fusion reaction processes with high Coulomb barriers:

D + D → He-4 + gamma (23.9 MeV) – minor D-D fusion branch ~10^{-5} %

D + D → Tritium + proton (4.03 MeV) – BR ~50%

D + D → He-3 + neutron (3.27 MeV)) – BR ~50%

D + Tritium → He-4 + 14.1 MeV neutron (17.6 MeV)

This data illustrates how LENRs may have the potential to be a much better power generation technology than hot fusion; they release just about as much energy without energetic neutrons or gamma radiation

Powering the world to a green future

LENRs and the future of global power generation

- ✓ Small-scale LENR systems might seem to be light years away from being able to compete with 500 - 1,000 MW coal-fired and Uranium-fission power plant behemoths. But please recall the history of personal computers versus mainframes. When PCs were first introduced 35 years ago, mainframe computer manufacturers regarded them as little toys; information processing 'jokes' of no consequence. Less than 10 years later, mainframe companies weren't laughing any more. Today, except for a handful of survivors like IBM, most mainframe and minicomputer 'dinosaurs' have disappeared. In fact, most of today's 'mainframes' actually contain internal arrays of commodity PC microprocessors

- ✓ Using a similar business strategy that combines high-volume manufacturing, aggressive pricing and distributed generation, the economic costs of electric power generation with coal and with LENRs could potentially converge in the not-too-distant future. Commercialized versions of LENR technologies could someday begin competing directly with 'king coal,' oil, and natural gas as another primary energy source

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LENRs and the future of global power generation

- ✓ At system power outputs of just 5 - 10 kW, ‘green’ LENR-based distributed power generation systems providing heat and electricity could potentially satisfy the requirements of a majority of urban and rural households and smaller businesses worldwide
- ✓ At system power outputs of just 50 - 200 kW, LENR-based systems could begin to power steam or electric vehicles, breaking oil’s stranglehold on transportation; also provide high-quality heat for industrial processes
- ✓ Although they could very likely be designed and built, megawatt LENR systems are not mandatory to change the world of energy for the better
- ✓ If widespread deployment of small-scale distributed generation could be achieved, nowhere near as many new, large fossil-fired and/or fission power generation systems would have to be built to supply competitively priced electricity to regional grids serving urban and many rural areas. In that case, grid-based centralized power generation would be gradually displaced by vast numbers of smaller, lower-cost distributed systems

Powering the world to a green future

LENRs and the future of global power generation

- ✓ **Development of low cost LENR-based portable and small-scale stationary systems could revolutionize 'green' CO_2-free distributed power generation worldwide; it could potentially enable near-ubiquitous LENR system deployment, and eventually permit universal global electrification at readily affordable societal costs**
- ✓ **Achievement of that goal would end 'energy poverty' for ~1.6 billion people presently living in rural areas of our world that do not have *any* non-battery sources of local electric power generation --- grid-based, distributed stationary, mobile fossil-fueled gensets, or otherwise**
- ✓ **Use of a distributed LENR power generation strategy to provide full rural electrification could save countries like China and India many hundreds of billions if not trillions of yuan and rupees in investments that would otherwise have to be made to expand geographic coverage of presently limited-area electrical grids. The same is true for rural Africa, as well as hinterlands of the Middle East and South America**

Powering the world to a green future

Future of energy: LENRs and distributed power generation

Strategy is advantageous in industrialized countries and grid-less rural areas

Increases the stability and robustness of modern grids and brings power to the powerless

- ✓ **A bold vision of the future of distributed power generation, "Micropower: the next electrical era," by Seth Dunn was published by the Worldwatch Institute (2000) http://www.worldwatch.org/system/files/EWP151.pdf**

- ✓ **"Perfect power: how the microgrid revolution will unleash cleaner, greener, and more abundant energy," Bob Galvin and Kurt Yeager (2008)**

- ✓ **In Lattice's opinion, paradigm-shifting LENRs are vastly bigger than any one company, however large, and bigger than any one country, however powerful ---- if there is such a thing, LENRs are truly a world technology**

Powering the world to a green future

Working with Lattice

We are commercializing LENRs and consult to advance LENR technology

"There is first the groping after causes, and then the struggle to frame laws. There are intellectual revolutions, bitter controversial conflicts, and the crash and wreck of fallen philosophies."

Francis Venable "A Short History of Chemistry," pp. 1 D. C. Heath 1894

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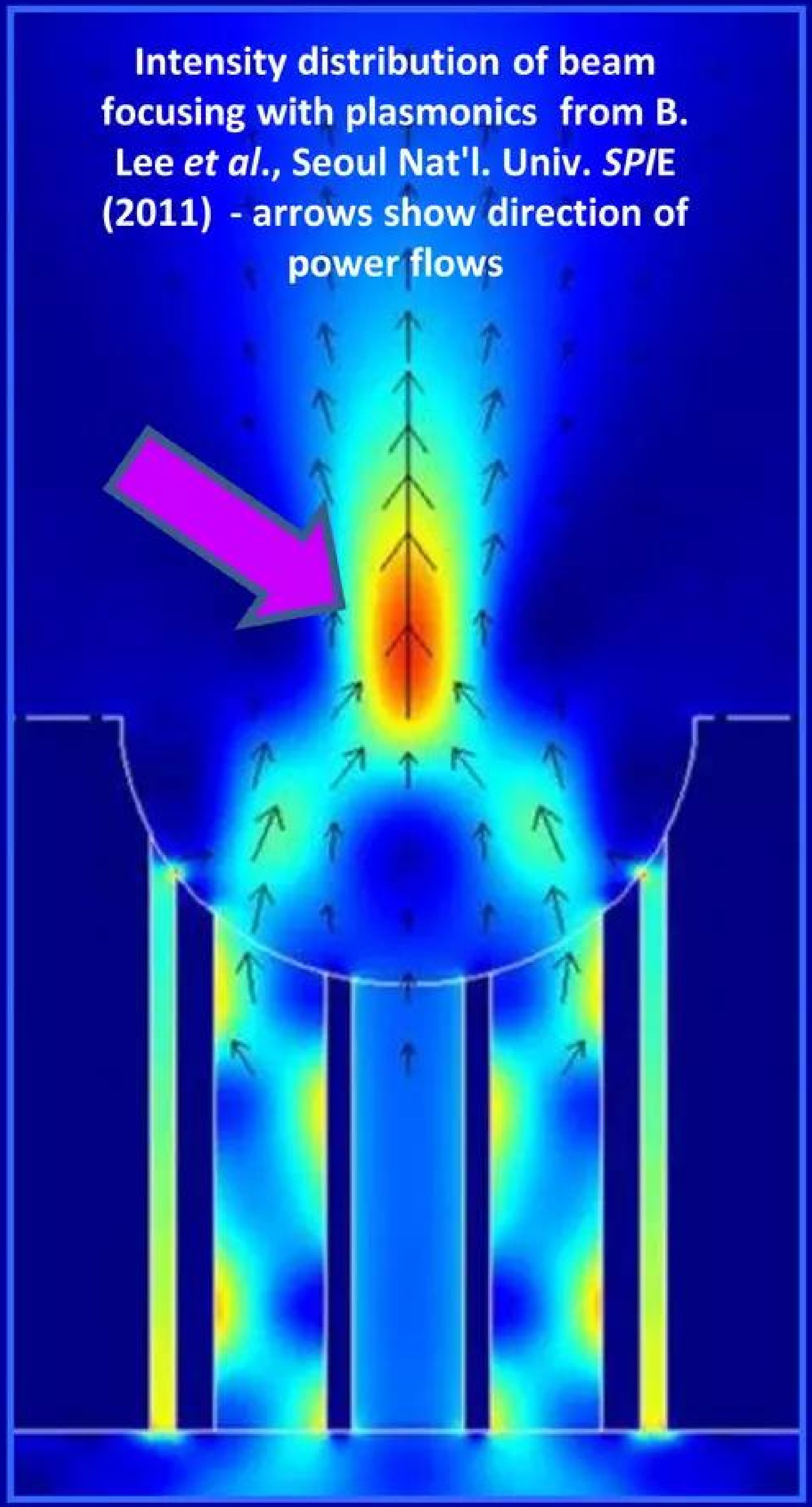
Working with Lattice

We are commercializing LENRs and consult to advance LENR technology

1-312-861-0115   lewisglarsen@gmail.com

- ✓ **Lattice welcomes inquiries from large, established companies that have an interest in seriously discussing the possibility of becoming a strategic capital and/or technology development partner in the near- or long-term time frames**
- ✓ **We also welcome inquiries from financial principals of substance whether they may be professional institutional investors or individuals; as a matter of policy Lattice will not deal with any financial intermediaries; please note that most individual investors would find our minimums to be daunting and out-of-reach**
- ✓ **To augment working capital and promote further development of LENR technology, Lattice also selectively engages in some fee-based third-party consulting. This work covers various topics in the context of micron-scale, many-body collective quantum effects in condensed matter systems (including photosynthesis), field failures involved in Li-ion battery thermal runaways, nuclear waste remediation, and ultra-high-temperature superconductors, among others. Additional areas of expertise include long-term strategic implications of LENRs on high cap-ex investments in power generation and petroleum-related assets, as well as long-term price outlooks for precious metals and crude oil. We consult on any of these subjects as long as it does not involve disclosing proprietary engineering details applicable to Lattice's planned LENR power generation systems. Consulting is subservient to the company's main goal: commercializing LENRs for applications in ultra-high energy density portable, mobile, and stationary power generation systems**
- ✓ **Larsen c.v.: http://www.slideshare.net/lewisglarsen/lewis-g-larsen-cv-june-2013**

Concentrating E-M energy in resonant electromagnetic cavity



Intensity distribution of beam focusing with plasmonics from B. Lee *et al.*, Seoul Nat'l. Univ. *SPIE* (2011) - arrows show direction of power flows

http://spie.org/documents/Newsroom/Imported/003435/003435_10.pdf

Powering the world to a green future

Working with Lattice

Lattice's approach to R&D and engineering on LENRs is uniquely nanocentric

- ✓ At the present stage of LENR technology (TRL-2), trying to immediately fabricate nm- to cm- scale and larger LENR devices that are supposed to produce macroscopically large fluxes of excess heat and rapidly "boil a cup of tea" is really putting the cart before the proverbial horse
- ✓ Unlike its competitors, Lattice plans to use its unique proprietary knowledge of LENR physics, nanotech-based device fabrication strategies, and key operating parameters (e.g., achieving and maintaining very high local surface electric fields) to first get key LENR effects --- such as maximizing $e^{-}p^{+}$ area-densities, maximizing ULM neutron production in 'patches', reliably fabricating key nanostructural design features, excess heat production, choice of 'target fuels', 'guiding' of transmutation reaction pathways and products, etc. --- working reliably on microscopic length scales in very small laboratory-grade nanodevices that have intentionally limited numbers of potentially LENR-active surface 'patch' sites
- ✓ That is, to be able to cause LENR effects to occur reproducibly on specific nanoparticulate structures with dimensions ranging from nanometers to microns that are fabricated using existing, off-the-shelf nanotechnology techniques and methods and deliberately emplaced, along with suitable 'target fuel' nuclei (e.g., Lithium atoms) in close proximity, on specific types of purpose-built nanostructures located on loaded metallic hydride surfaces
- ✓ Once these key technical goals have been successfully achieved and LENR processes are working extremely well on nanoscale regions of Lattice's laboratory R&D devices, scaling-up total device-level heat outputs could then be achieved simply by increasing the total number of emplaced LENR-active 'hot spot' sites per cm^2 of effective working surface area
- ✓ Lattice's nanocentric approach to LENR R&D is also unique in that it is highly interdisciplinary, being guided by various aspects of W-L theory and applying relevant knowledge adapted from advanced materials science, plasmonics, and nanotechnology

Powering the world to a green future

Working with Lattice

Lattice needs capital and strategic corporate partners to develop prototypes

- ✓ **Goal of planned US$25 - 30M engineering program is to produce system-level prototype LENR heat sources within 2-3 years of full funding**
- ✓ **Results achieved with two different types of device prototype embodiments ('target' nanoparticles affixed to substrate surfaces vs. nanoparticle injection into dusty plasmas) will determine next set of engineering goals. If both approaches deemed successful, will continue on two tracks toward both small- and large-scale commercial systems**
- ✓ **Upon successfully reaching this milestone, final time-to-market will be determined by: availability of needed capital; whether any surprises have arisen in scale-up engineering or product safety; and Lattice's ability to secure large strategic corporate R&D and marketing partners who can further accelerate product development and market penetration**
- ✓ **Possible first-products include 3-5 kW standalone stationary electrical power generation systems and well-hole heaters for oil & gas industry**

Powering the world to a green future

LENRs and paradigm-shifting technological revolution

"I cannot help fearing that men may reach a point where they look on every new theory as a danger, every innovation as a toilsome trouble, every social advance as a first step toward revolution, and that they may absolutely refuse to move at all."[1.]

"In a revolution, as in a novel, the most difficult part to invent is the end."[2.]

Alexis de Tocqueville (1840)

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1. *"Democracy in America"* Volume II Book Three, Chapter XXI – "While great revolutions will become more rare" (1840)
http://www.gutenberg.org/files/816/816-h/816-h.htm
http://www.gutenberg.org/files/816/816-h/816-h.htm#link2HCH0062

2. *"The Recollections of Alexis de Tocqueville"*, Alexis de Tocqueville, pp. 71 Macmillan (1896)