LENRs and the Future of Energy

Low Energy Neutron Reactions or LENRs

Truly green nuclear process: no deadly radiation or long-lived wastes

Hidden in plain sight for 100 years because hard radiation is absent

2013: device physics sufficiently understood to begin commercialization

1945

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November 27, 2013

Evolution of nuclear technology

2013

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LENRs and the Future of Energy

LENRs are a paradigm-shifting nuclear technology

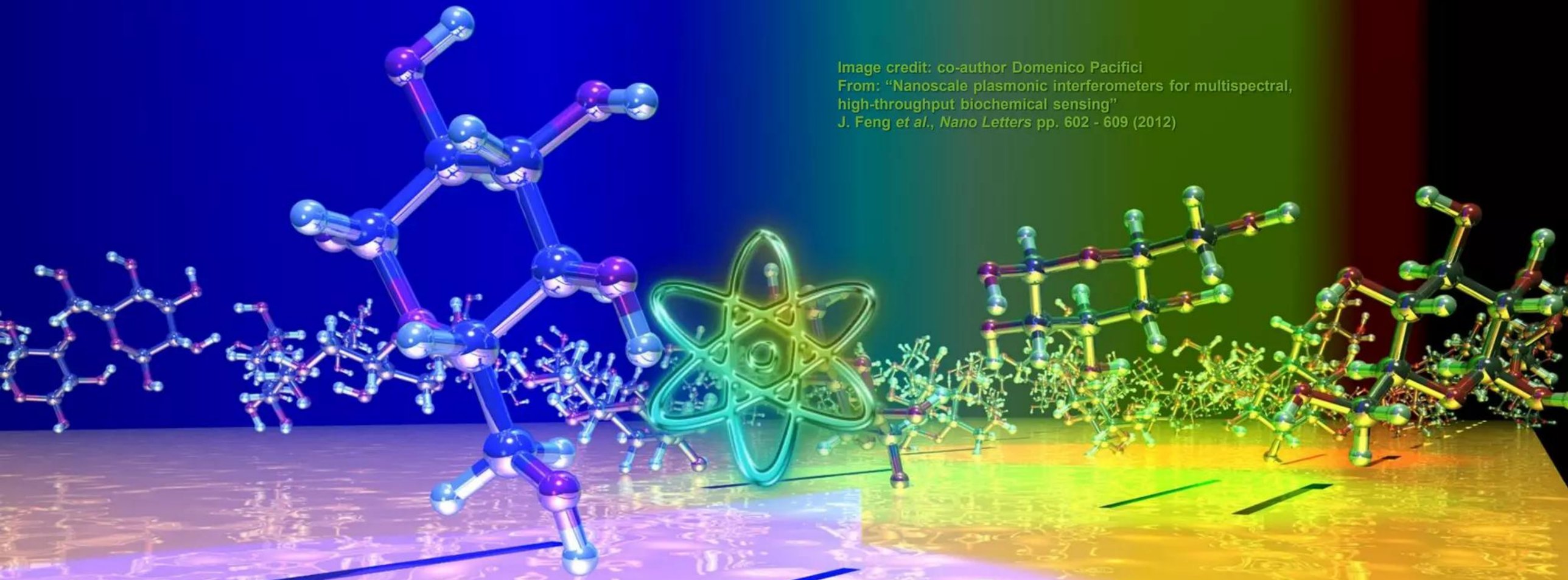


Image credit: co-author Domenico Pacifici
From: "Nanoscale plasmonic interferometers for multispectral, high-throughput biochemical sensing"
J. Feng *et al.*, *Nano Letters* pp. 602 - 609 (2012)

No deadly gamma radiation …

No dangerous energetic neutron fluxes and

Insignificant production of nasty radwastes

Truly revolutionary and environmentally safe

LENRs and the Future of Energy

LENRs are neither fission nor fusion but something rather different and wonderful

LENRs and the Future of Energy

LENRs differ greatly from fission and fusion technologies

Lack of hard radiation obviates need for shielding and containment

Opportunity to develop safe, battery-like portable LENR power sources

Fission reactors need 1 foot of steel and 3 feet of concrete to protect humans from hard radiation and wastes emitted by reactor; makes systems intrinsically large and heavy

Evolution of nuclear technology

LENRs enable devices something like this: small, portable battery-like power sources that are safe and disposable

Much larger LENR devices based on dusty plasma embodiments can potentially scale-up to megawatts; akin to today's power plants

LENRs and the Future of Energy

Comparison of competing nuclear power technologies

Fission and fusion emit hard radiation and produce radioactive wastes

LENRs do not emit any hard radiation or create environmentally harmful wastes

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

Heavy-element fission (involves shattering heavy nuclei to release stored nuclear binding energy):
Requires massive shielding and containment structures to handle radiation; major radioactive waste clean-up issues and costs
Alternate natural sources of fuel: today, almost entirely Uranium; Thorium-based fuel cycles now under development
Heavy element U-235 (fissile isotope fuel) + neutrons → (complex array of lower-mass fission products; some are very long-lived isotopes) + energetic gamma radiation + energetic neutron radiation + energy

Fusion of light nuclei: (involves smashing light nuclei together to release stored nuclear binding energy):
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 radioactive 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):
An 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 target nuclei then proceed from lower to higher values of atomic mass (A); very similar to what happens in stars, only at low temps/pressures

LENRs and the Future of Energy

1929: Atkinson & Houtermans theorize light element fusion

1932: Chadwick experimentally verifies existence of the neutron

1934: Rutherford, Oliphant & Harteck experimentally trigger D fusion

1939: Bethe theorized that H fusion reactions power the stars

$$D + D \rightarrow H^3 \text{ (Tritium)} + \text{proton}$$

$$D + D \rightarrow He^3 \text{ (Helium-3)} + \text{neutron}$$

$$D + T \rightarrow He^4 \text{ (Helium-4)} + \text{neutron}$$

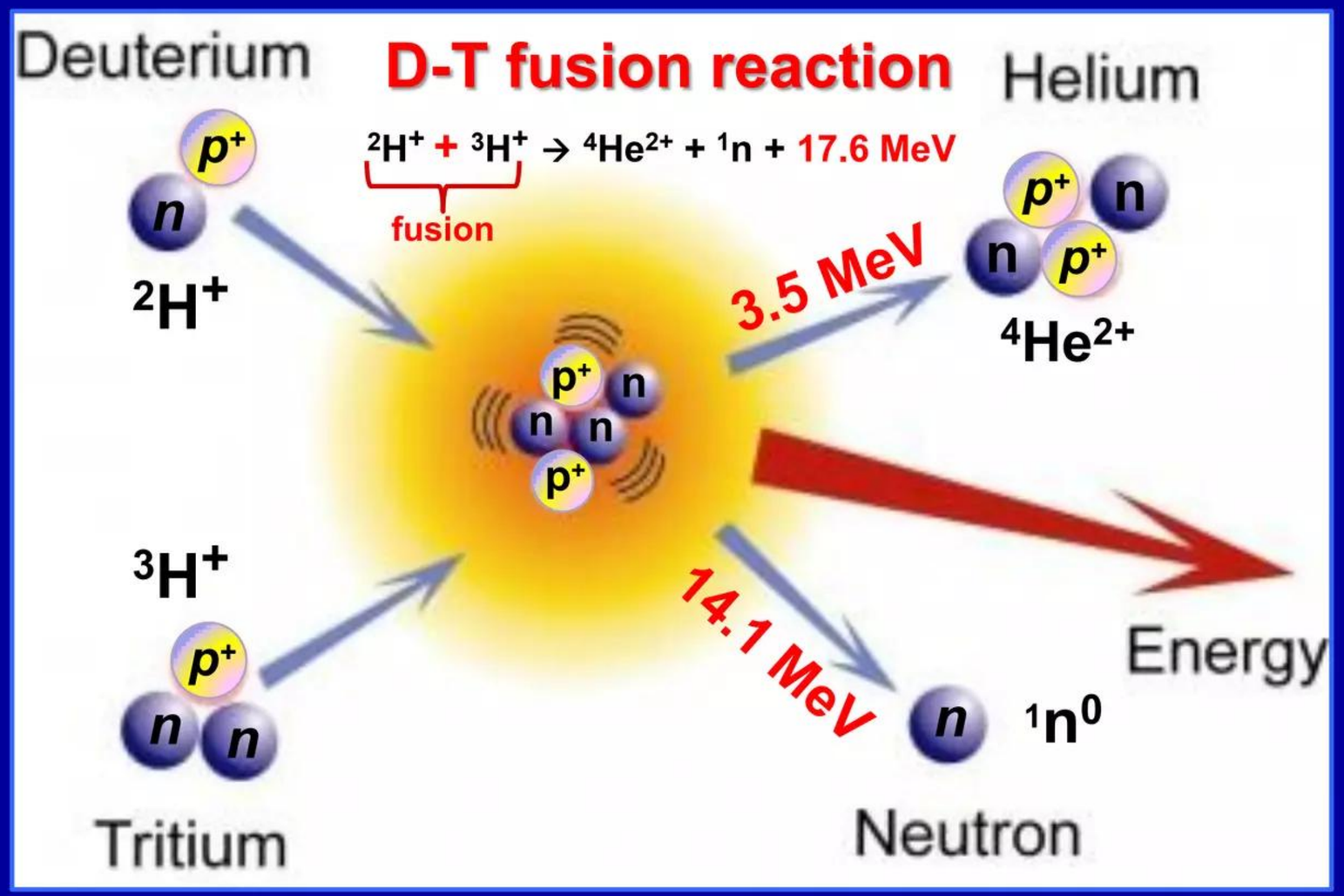
Deuterium + Tritium reaction has been Holy Grail of fusion R&D

LENRs and the Future of Energy

Government R&D programs chased D-T fusion for 60 years

Easier vs. other fusion reactions but creates very energetic neutrons

Still decades from commercialization: ITER reactor in Cadarache, France



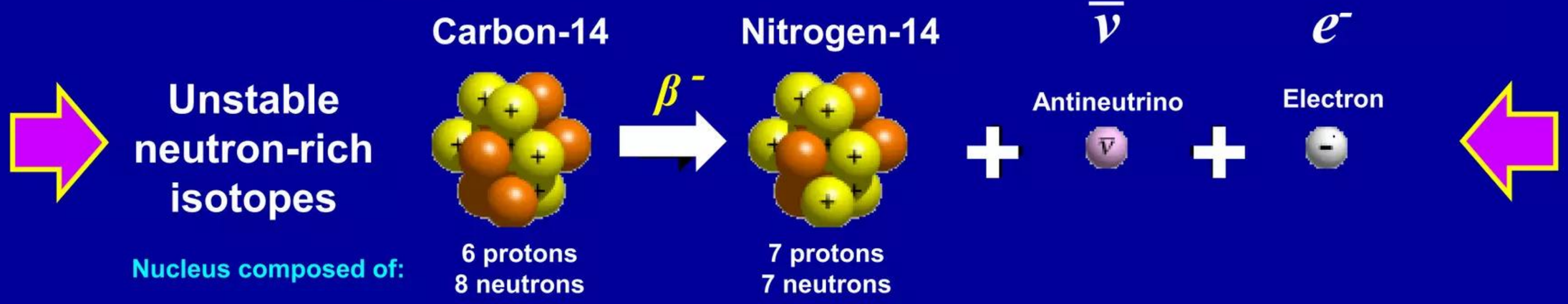
LENRs and the Future of Energy

1934: Fermi published theory of beta decay w. neutrinos

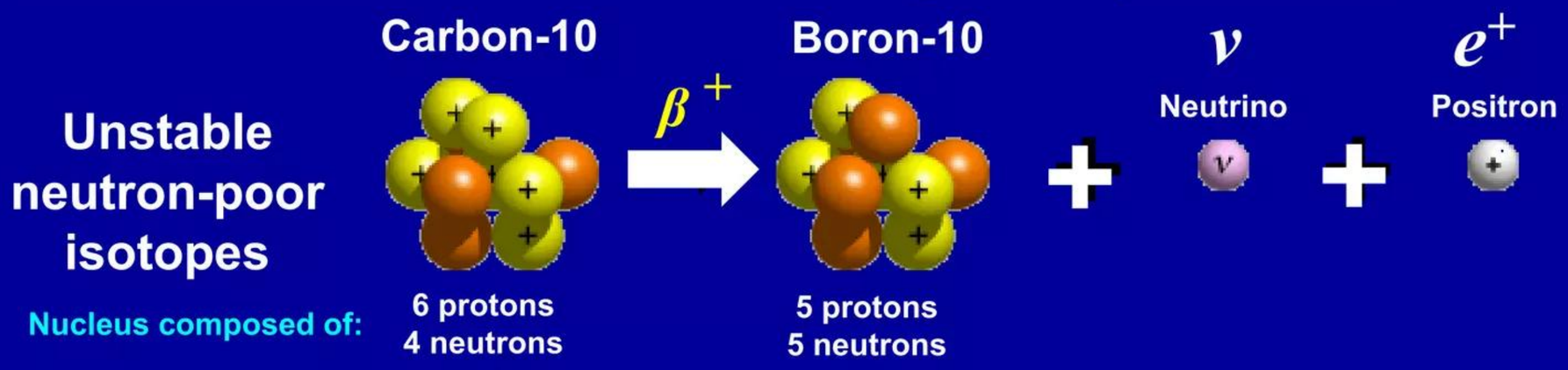
Beta$^-$ decay processes important contributor to 'greenness' of LENRs

Beta decay reactions can release substantial amounts of nuclear binding energy

Beta-minus decay (β^-): one neutron spontaneously converts into a proton

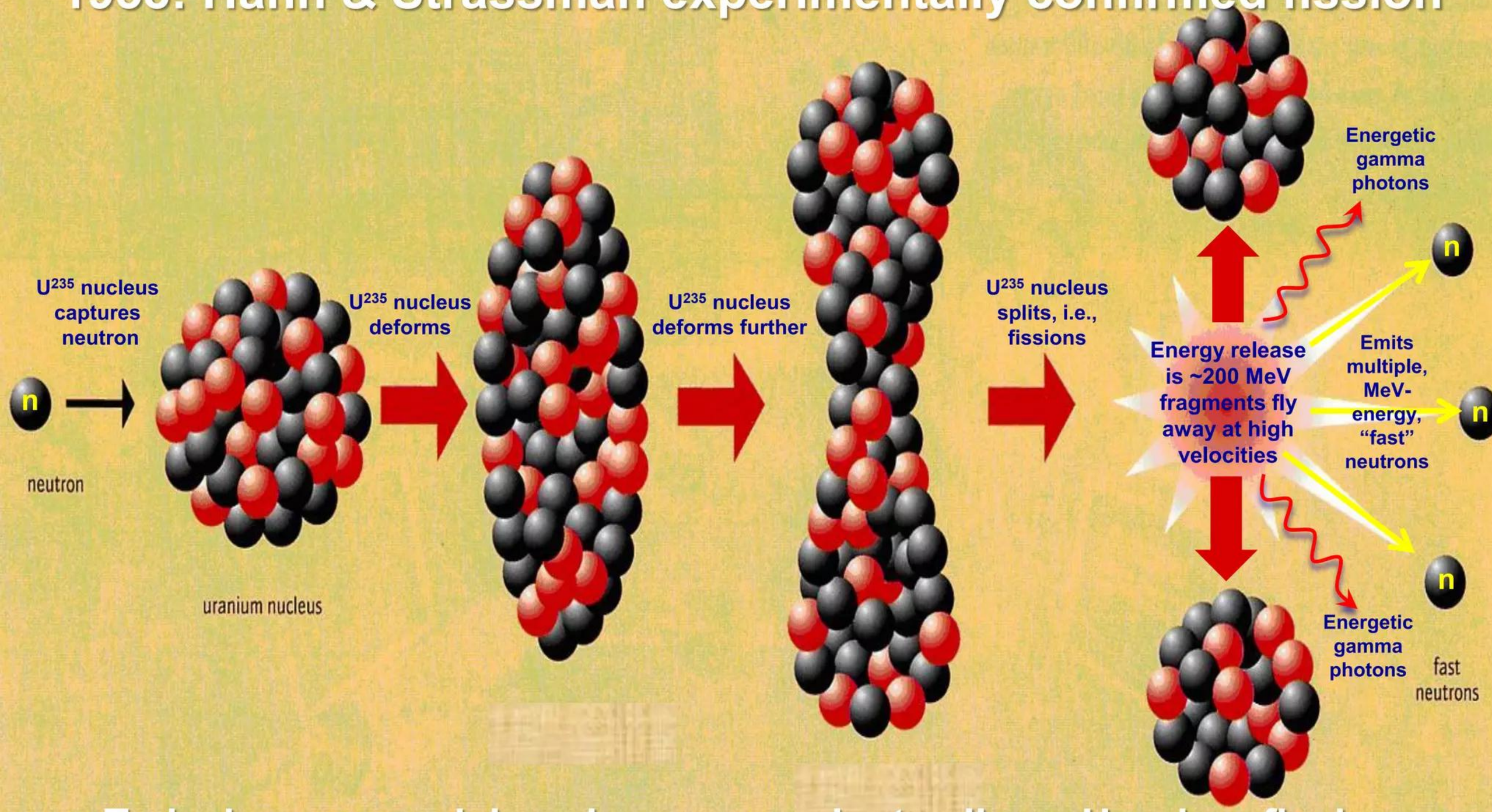


Beta-plus decay (β^+): one proton spontaneously converts into a neutron



LENRs and the Future of Energy

1938: Hahn & Strassman experimentally confirmed fission



Today's commercial nuclear power plants all use Uranium fission

LENRs and the Future of Energy

1946: Hoyle theorized e + p reactions in dying stars

Core-collapse triggers e + p at gigantic temps/pressures in supernova

Dying star explodes, creating much heavier elements and remnant neutron star

Deep in super-dense, unbelievably hot inner cores of dying stars, electrons e^- are able to directly react with protons p^+ to create huge numbers of very energetic neutrons n^0

Having no net electric charge, neutrons are promiscuous nuclear particles that will be very quickly captured (i.e., absorbed) by other atomic nuclei (elements) that are present in stars

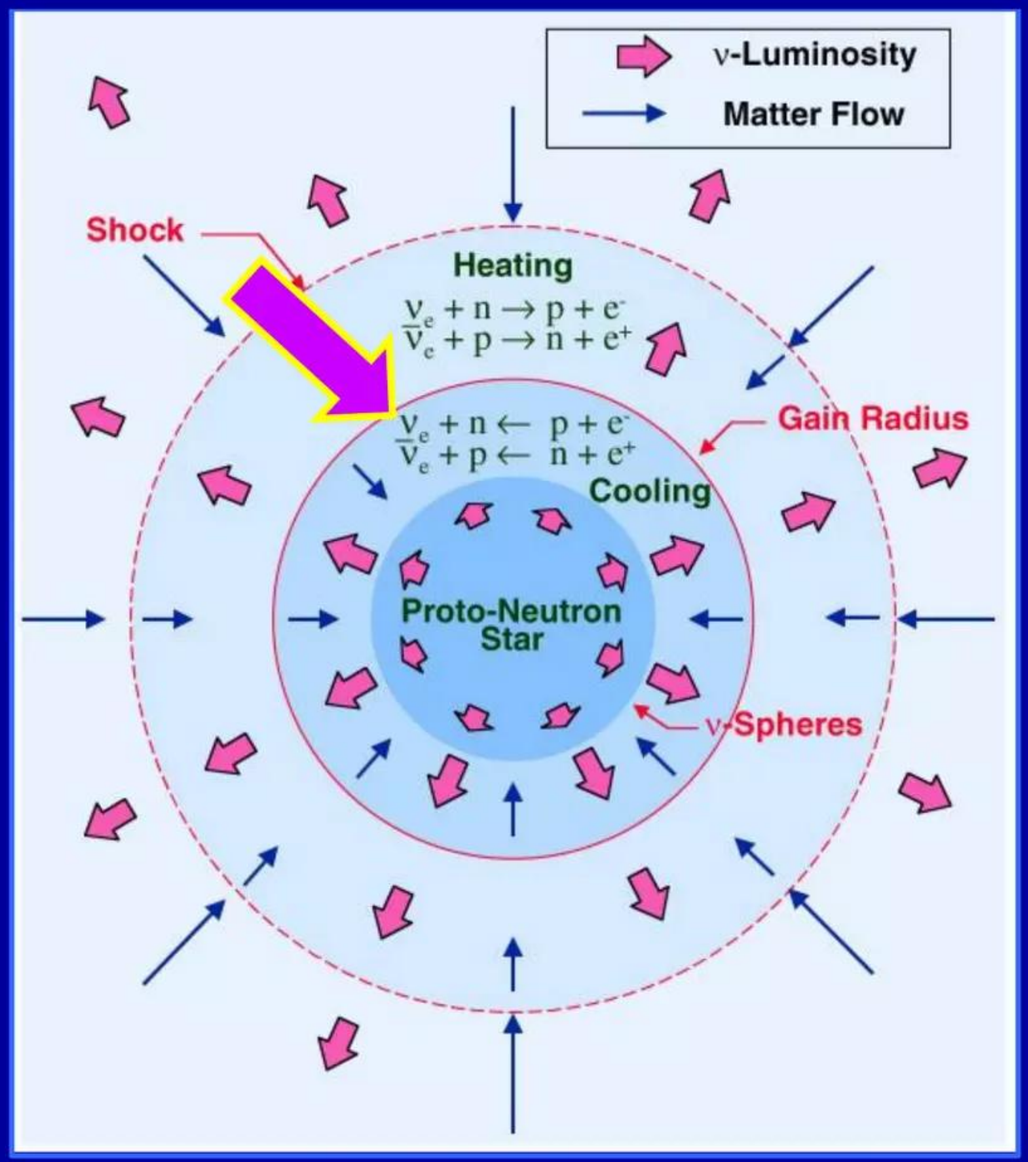


Image credit: TeraScale Supernova Initiative

Even under these incredibly extreme stellar conditions, the e^- + p^+ process is still ~ a two-body reaction

Two-body reactions require enormously high temperatures to create electron kinetic energies that impart enough additional mass-energy to fast electrons to make-up the "mass deficit" necessary to react directly with protons to make neutrons

LENRs and the Future of Energy

Astrophysics view of element creation in Universe

Older paradigm posits that nucleosynthesis can only occur in stars

Fusion up to Fe; from there neutron capture processes can reach superheavies

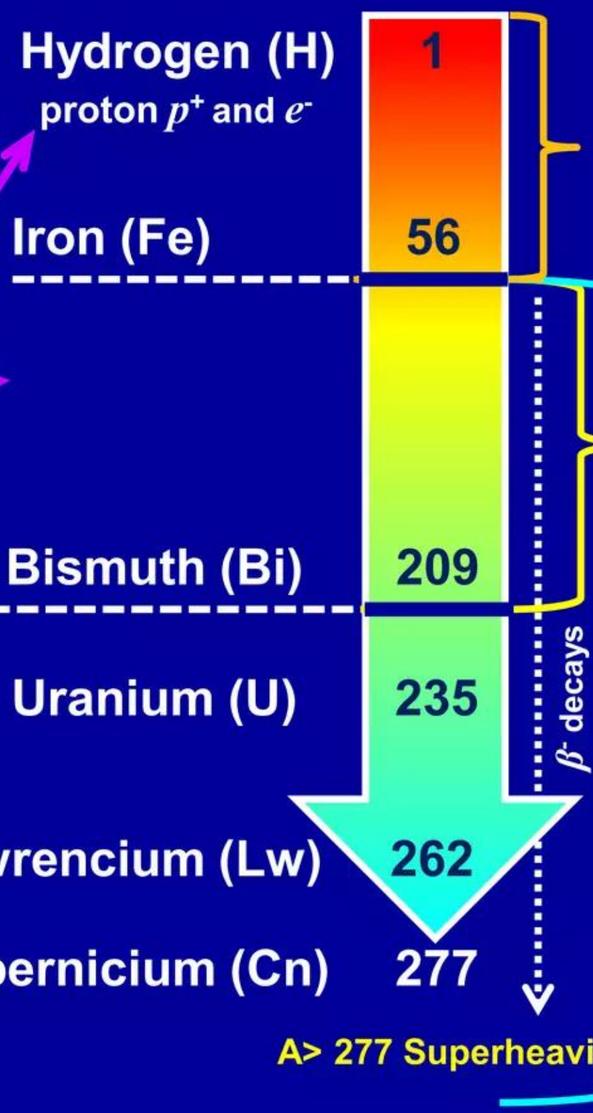
Fission and α-decay processes recycle heavy elements back into lighter ones (lower values of A)

Cosmic nucleosynthetic cycle in values of A

Proton emission from nuclei and neutron β-decay

Atomic Mass (A)

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



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

Fusion reactions: deep in cores of stars

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

s-process: thought to occur in outer envelopes of late-stage red giant stars

r-process: as of today, while most believe it occurs only in supernova explosions, nobody is 100% certain that idea is true

Neutron-capture (A+1$_n$): *r*-process operates from A~56 up to ???

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

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

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

LENRs and the Future of Energy

Scientists observed LENRs in experiments for > 100 years

Not recognized as being nuclear because no hard radiation emitted

Periodically resurfaced as unexplained anomalies in different guises

Early 1900s: many researchers reported seeing transmutation of elements during electric discharges

1922: Wendt & Irion reported producing Helium in exploding wires; Rutherford trashed their results

1925: Nagaoka reported producing Gold during electric arc discharges; few believed paper's results

1927: one of Millikan's PhD students reported heavy element transmutations; not generally believed

Early 1930s to 1950: dark ages of LENR transmutation research; not pursued by anyone anywhere

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

Mid-1960s: neutron production seen during RF excitation of Deuterium plasma; work was dropped

1989: Pons & Fleischmann claimed D+D "cold fusion" seen in electrolytic cell; trashed by scientists

2002: Mitsubishi Heavy Industries reported Cs to Pr transmutation in refereed journal; questioned

2006: Widom and Larsen published theory's key parts in peer-reviewed *European Physical Journal C*

2012: Mitsubishi Heavy Industries confirmed Nagaoka's LENR transmutation path to Gold at ANS

2013: Toyota finally confirmed Mitsubishi's LENR transmutation of stable Cesium → Praseodymium

LENRs and the Future of Energy

LENRs in context of historical events beginning in 1942

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: Prof. Fred 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 and L. Larsen released first theoretical preprint re LENRs on Cornell physics arXiv
2006: A. Widom and 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
2013: LENR device physics now understood well enough to begin commercialization for power

LENRs and the Future of Energy

LENRs are an incredibly interdisciplinary technology

Resisted understanding until Widom-Larsen put all pieces together

Nanometer-to-micron scale many-body collective effects enable the 'impossible'

Quantum electrodynamics (QED)

Collective many-body effects

Modern quantum mechanics

Condensed matter physics

Classical electrodynamics

Modern nuclear physics

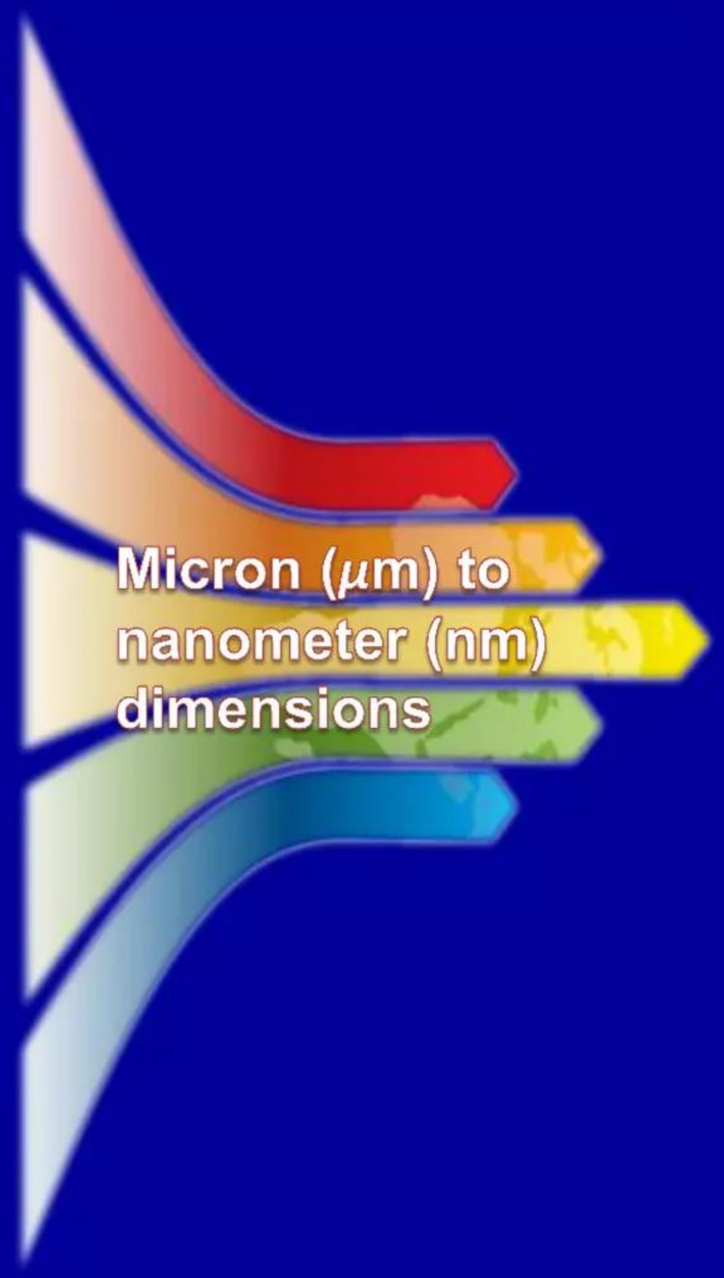
Surface chemistry (H)

All nanotechnology

Surface physics

Plasma physics

Plasmonics



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

LENRs and the Future of Energy

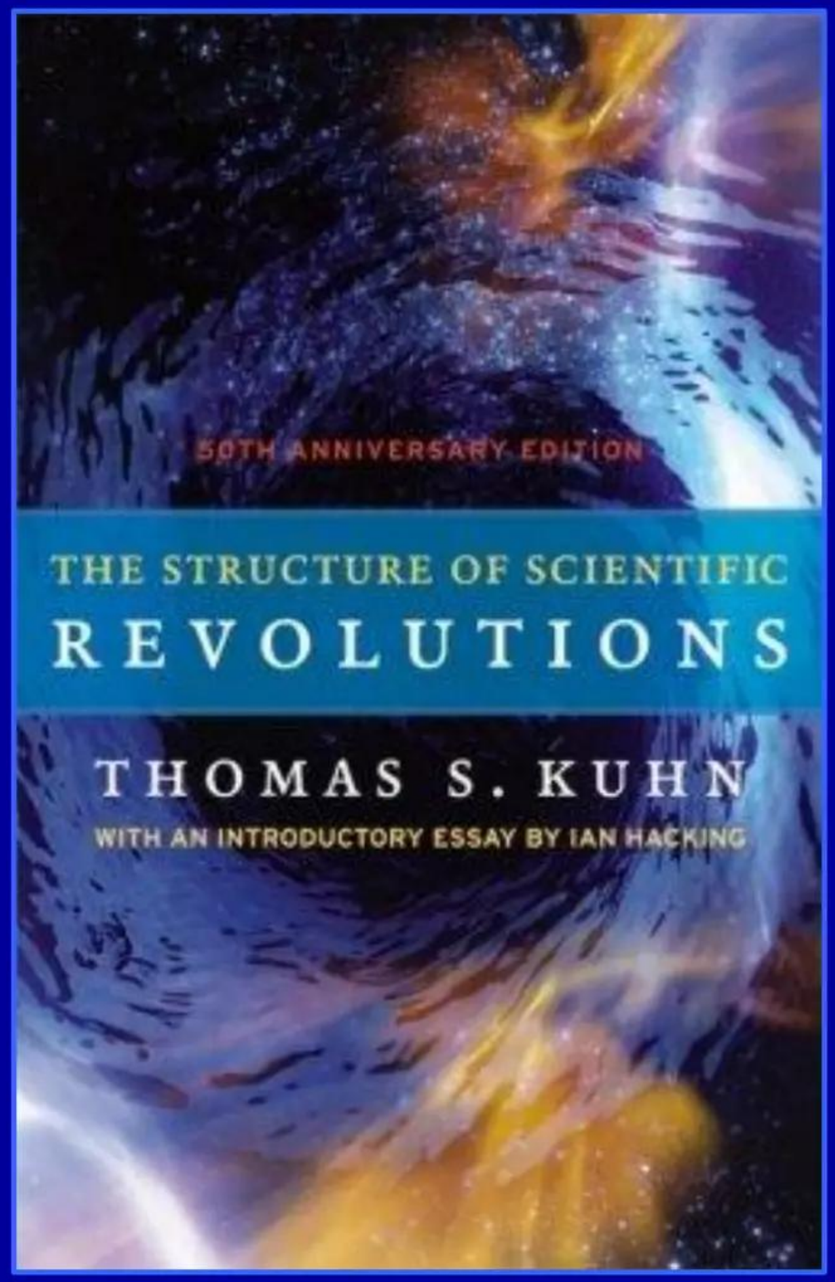
Revolution in energy technology is length-scale-related

Will trigger vast paradigm-shifting change in power generation systems

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

"Origination is not just a new way of doing things, but a new way of *seeing* things … And the new threatens … to make the old expertise obsolete. Often in fact, some version of the new principle [paradigm] has been already touted or already exists and has been dismissed by standard practitioners, not necessarily because lack of imagination. But because it creates a cognitive dissonance, an emotional mismatch, between the potential of the new and the security of the old." pp. 139

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



LENRs and the Future of Energy

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

Enabled by many-body collective effects along with quantum mechanics

No new physics in W-L theory: combines well-established physics in novel ways

- ✓ Since 1989, most previously proposed theories of LENRs presumed that Coulomb barrier-penetrating D-D fusion was taking place in LENRs. However, these earlier theories incorporated many *ad hoc* assumptions, invoked questionable "new physics," and were readily dismissed by mainstream physicists and chemists

- ✓ Prior to work of Widom-Larsen, no comprehensive theory of LENRs existed that was consistent with known physics and could explain results of ordinary hydrogen as well as deuterium experiments, correctly identify the cause of complex transmutation products, and be able to calculate observed reaction rates from first principles; only theory able to explain Prof. John Huizenga's "three miracles" discussed in highly critical 1993 book

- ✓ W-L theoretical work involves Standard Model interactions and many-body collective Q-M effects: explains all good experimental data on LENRs dating back to early 1900s, especially absence of 'hard' MeV-energy neutron or gamma radiation and negligible production of long-lived radioactive wastes; predicts new types of experimentally verifiable phenomena in condensed matter systems

If LENRs involved any fission or fusion, many researchers would have been killed by lethal doses of deadly hard radiation that would have invariably accompanied measurable excess heat

Frank Frazetta, "The Death Dealer" (1973)

LENRs and the Future of Energy

Many-body collective quantum effects enable LENRs

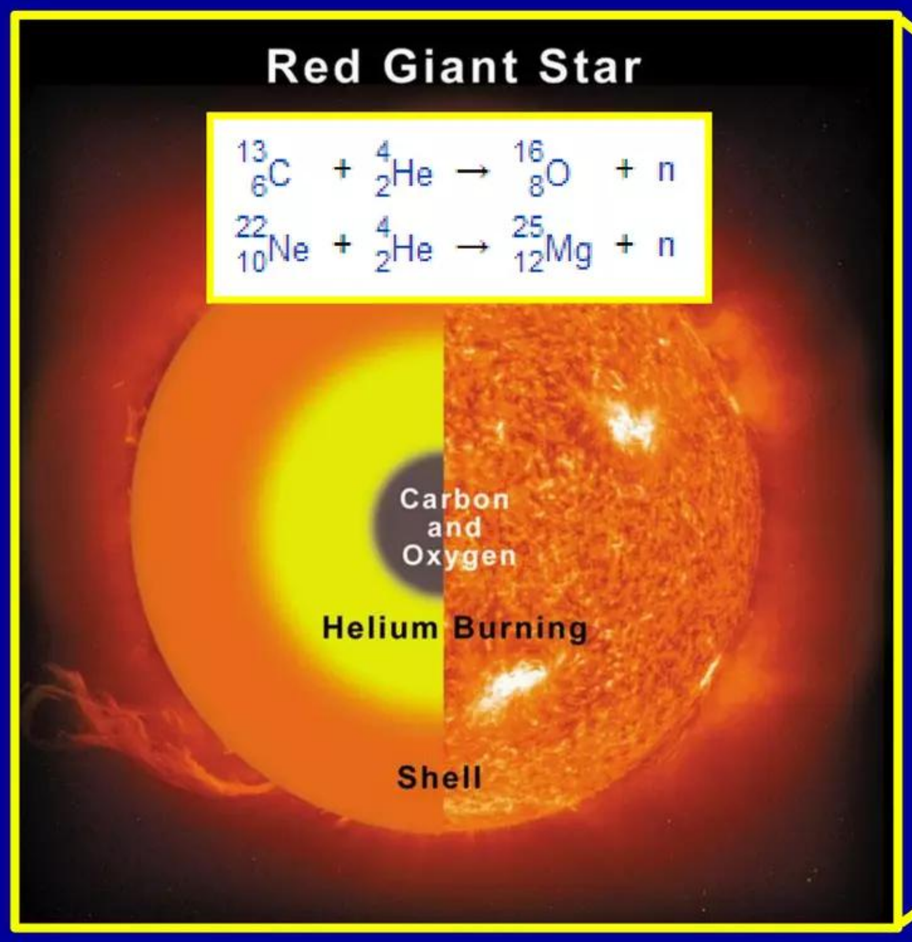
Do not need star-like temps/pressures to make neutrons from protons

Star-like nucleosynthesis of elements is therefore possible in tabletop systems

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

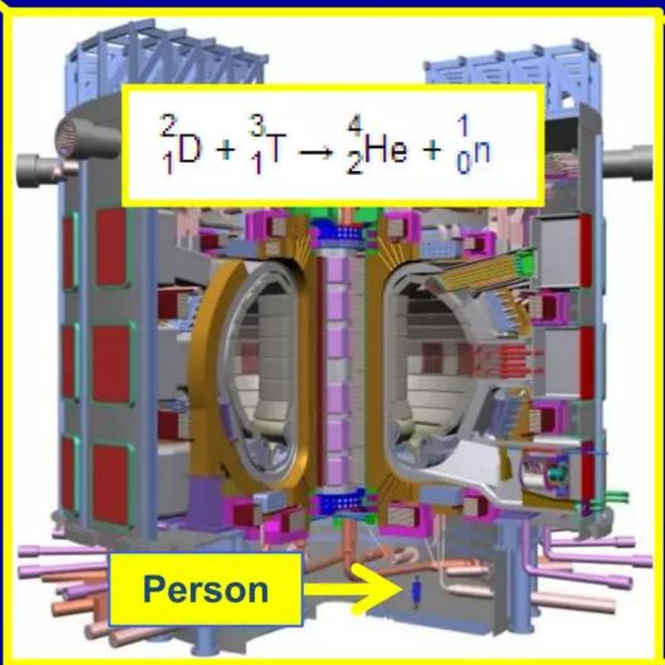
Widom-Larsen physics on small length-scales enables an energy revolution

All these reactions create neutrons (n)



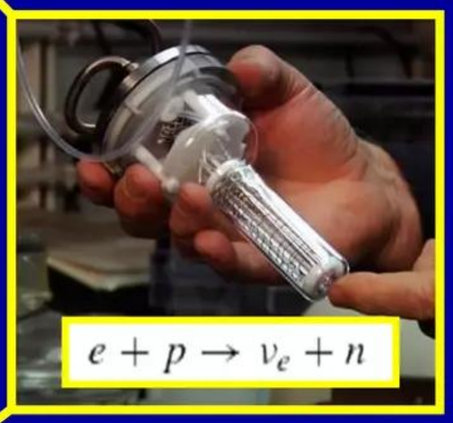
Length-scale: millions of miles

ITER: D-T fusion reactor



Length-scale: hundreds of feet

LENR device



Length-scale: inches

LENRs and the Future of Energy

Large length scales

Nuclear-strength surface electric fields in nm- to μ-sized active sites enable e + p reaction

What was thought impossible becomes possible at nm

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

LENRs and the Future of Energy

2006: W-L show how $e + p$ reaction occurs outside stars

Many-body collective effects enable $e + p$ at modest temps/pressures

Nucleosynthesis can thus happen in ordinary solid (condensed) matter systems

Synthesis of catalytic neutrons via a weak reaction:

Many-body collective effects + added input energy

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

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

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

Transmutation of atoms into other isotopes/elements:

Afterwards neutrons quickly capture on local atoms

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

$$(Z, A+1) \rightarrow (Z+1, A+1) + e^-_\beta + \nu_e \quad \text{[beta}^- \text{ decay]}$$

Mainly β^- decays of neutron-rich isotopic products

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: → + $(Z, A) \rightarrow (Z-2, A-4) + {}^4_2\text{He}$
		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.

LENRs and the Future of Energy

Further details about W-L LENRs in condensed matter

Many surface plasmon electrons can react with many surface protons

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

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

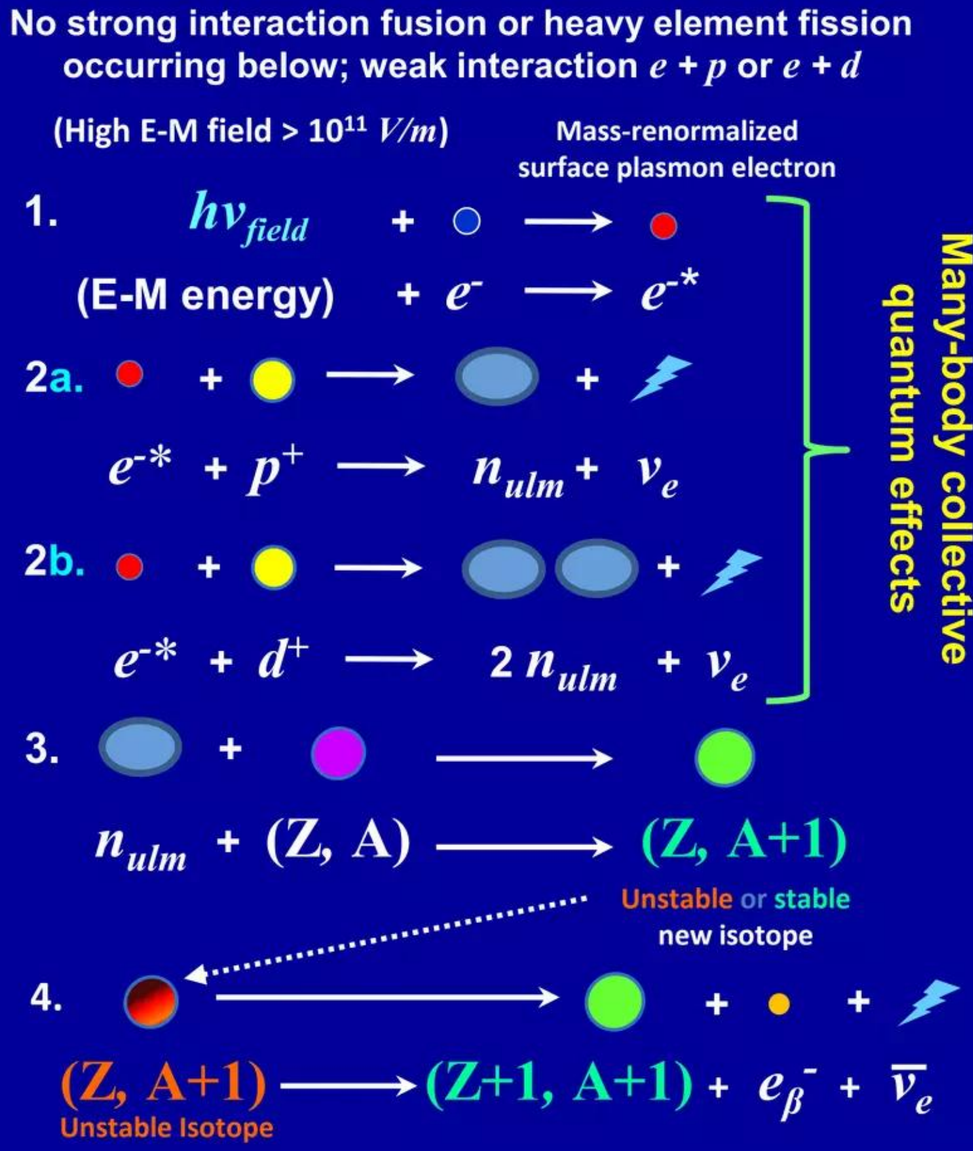
1. Electromagnetic (E-M) radiation on a metallic hydride surface increases mass of surface plasmon (SP) electrons

2. Heavy-mass surface plasmon electrons react directly with (a) surface protons (p^+) or (b) deuterons (d^+) to produce ultra low momentum (ULM) neutrons (n_{ulm} or 2 n_{ulm}, respectively) and an electron neutrino (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



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

LENRs and the Future of Energy

Basic reactions in Widom-Larsen theory are simple

Protons or deuterons react directly with electrons to make neutrons

Neutrons are then captured by other atoms → catalyze nuclear transmutations

Collective many-body quantum effects: many electrons each donate little bits of energy to a much smaller number of electrons that are also embedded in same high electric field

Quantum electrodynamics (QED): smaller number of electrons that absorb energy from electric field can increase their effective masses ($m = E/c^2$) to point where they can react directly with protons (or deuterons) to make neutrons and neutrinos

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

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

Neutron-catalyzed nucleosynthetic transmutation processes:

Neutrons + nearby atoms → heavier elements + decay products

Releases large amounts of nuclear binding energy as energetic particles and photons that heat

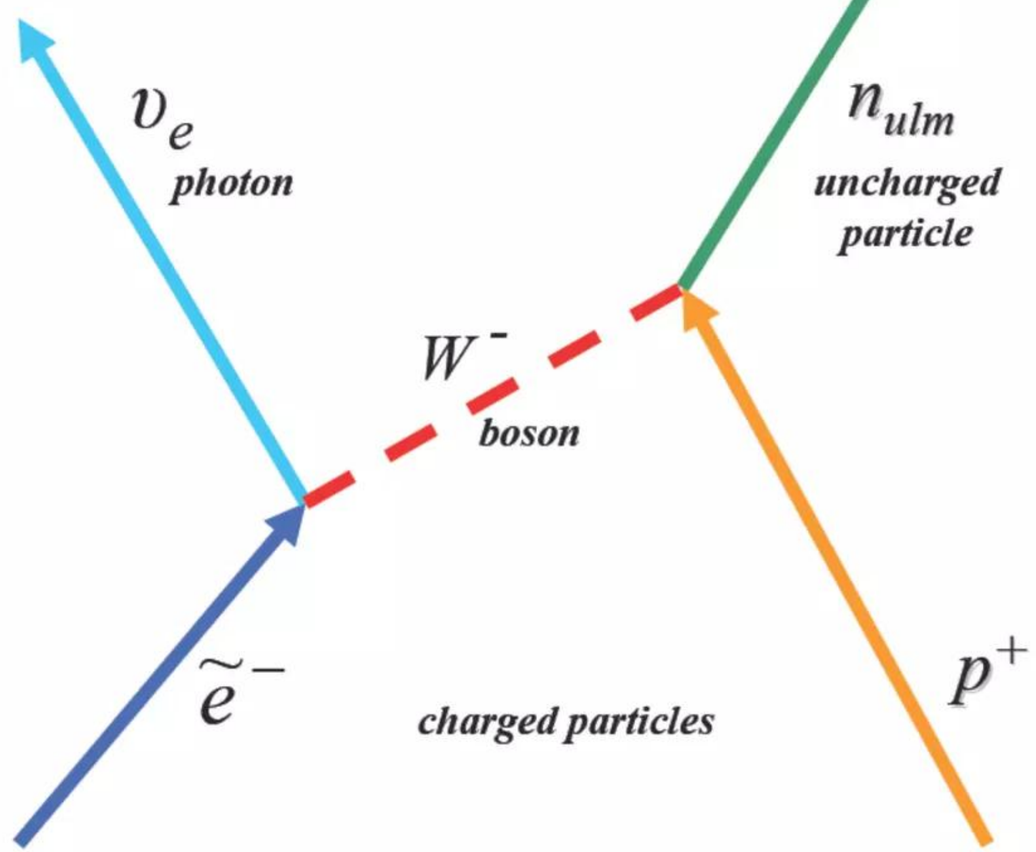
LENRs and the Future of Energy

Many-body collective quantum effects are key to LENRs

Written as two-body e^{-}* + p^{+} reaction --- what happens in Nature is many-body

LENR many-body collective effects also involve mutual quantum entanglement

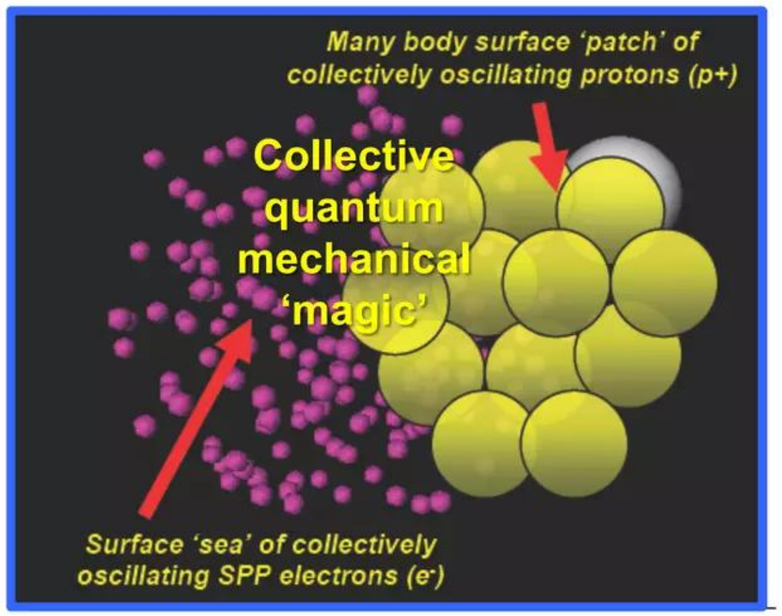
Simple two-body collision shown in Feynman diagram below:



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

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 in condensed matter systems

LENRs and the Future of Energy

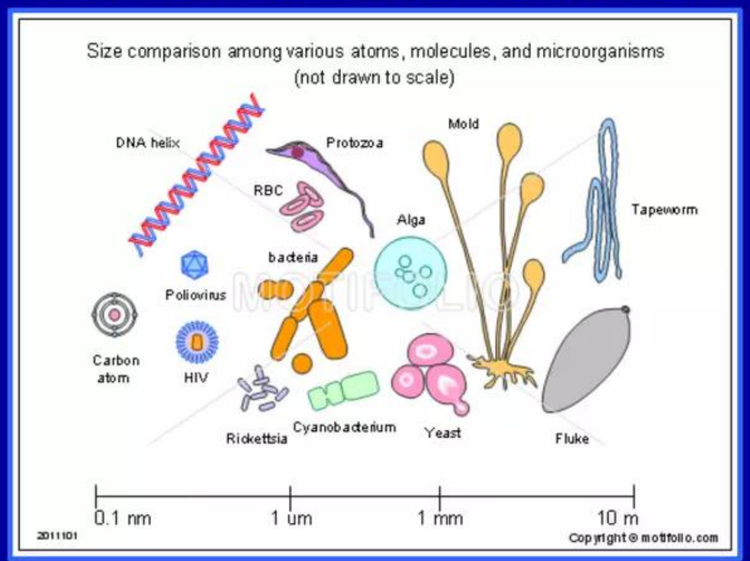
LENRs do not emit any deadly MeV-energy neutron fluxes

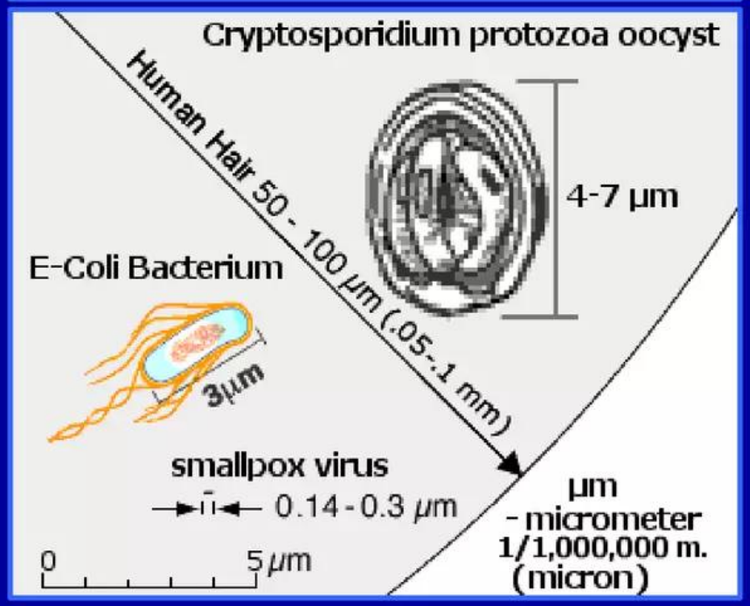
Neutrons created by W-L collective process have ultra low energy

Causes them to have huge quantum mechanical de Broglie wavelengths

- ✓ Collectively produced LENR neutrons are created with kinetic energies that closely approach a value of zero
- ✓ According to quantum mechanics, this means that their de Broglie wavelengths will have to be extremely large; for technical reasons explained elsewhere, de Broglie wavelengths of such neutrons must span dimensions of the LENR-active surface patches that first created them
- ✓ Diameters of LENR-active surface patches range from 2 nanometers (nm) up to ~100 microns --- this determines neutron de Broglie wavelength dimensions; for instants, normally subatomic fm neutrons are the sizes of bacteria
- ✓ Neutrons with de Broglie wavelengths this huge will be captured locally within picoseconds; never have quite enough time to thermalize and escape into environment
- ✓ This is why LENRs do not emit dangerous MeV neutrons

Examples of objects on varied length-scales





LENRs and the Future of Energy

LENRs do not emit deadly fluxes of MeV-energy gammas

Unreacted heavy electrons in LENR patches convert γ-rays into heat

Convert gamma radiation in energy range: ~0.5 MeV up to ~10 - 11.0 MeV

- ✓ **Unreacted heavy-mass SP electrons in LENR-active surface patches can actively absorb and directly convert either locally emitted or incident gamma photon radiation in energy range of ~0.5 MeV up to ~10 - 11 MeV into much larger numbers of less-energetic infrared (IR) photons at high efficiency; process conserves energy**
- ✓ **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 such atoms. Since this prompt capture-related gamma radiation occurs inside 3-D quantum mechanical structure of a 3-D LENR-active patch, there are perforce always heavy electrons available nearby to absorb and convert such gamma emissions into IR**
- ✓ **Lattice awarded a patent on process: US #7,893,414 B2**

Direct conversion of gammas into infrared heat

Lattice fundamental patent: US #7,893,414 B2

LENRs and the Future of Energy

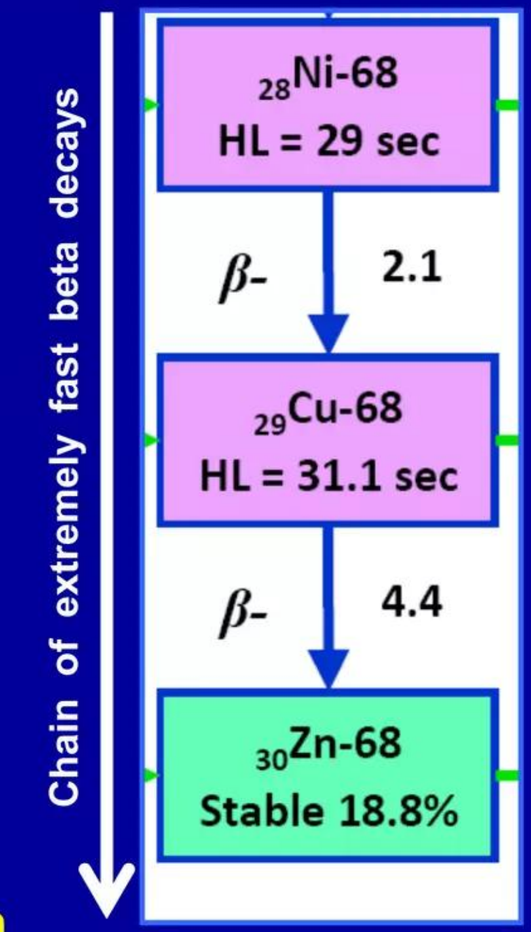
LENRs do not create large amounts of long-lived radwastes

Trick is to create unstable neutron-rich products that decay quickly

β^- cascades start with unstable isotopes that decay into stable elements

- ✓ Fluxes of ULM neutrons will cause a build-up of local populations of unstable, extremely neutron-rich isotopes comprising intermediate LENR transmutation products
- ✓ At some point during limited lifetime of tiny LENR-active patches, almost all such very unstable isotopes present will quickly decay, mainly by a series of fast β^- decay cascades
- ✓ Depending on the half-lives (HL) of intermediate LENR products, ULMN captures and β^- decay chains can rapidly traverse entire rows of periodic table, finally ending with creation of end-products that are almost invariably stable isotopes of higher-Z elements (see one example to right)
- ✓ β^- decay cascades explain why complex LENR transmutation networks almost never produce any significant amounts of biologically hazardous, nasty long-lived radioactive wastes

β^- decay cascade to stable Zinc



Nickel-68 is a product of neutron captures on stable Nickel isotopes, β^- decays transmute ^{68}Ni to stable Zinc

LENRs and the Future of Energy

LENR transmutations can be triggered in chemical cells

Electric current input to electrolytic cells can create multiple elements

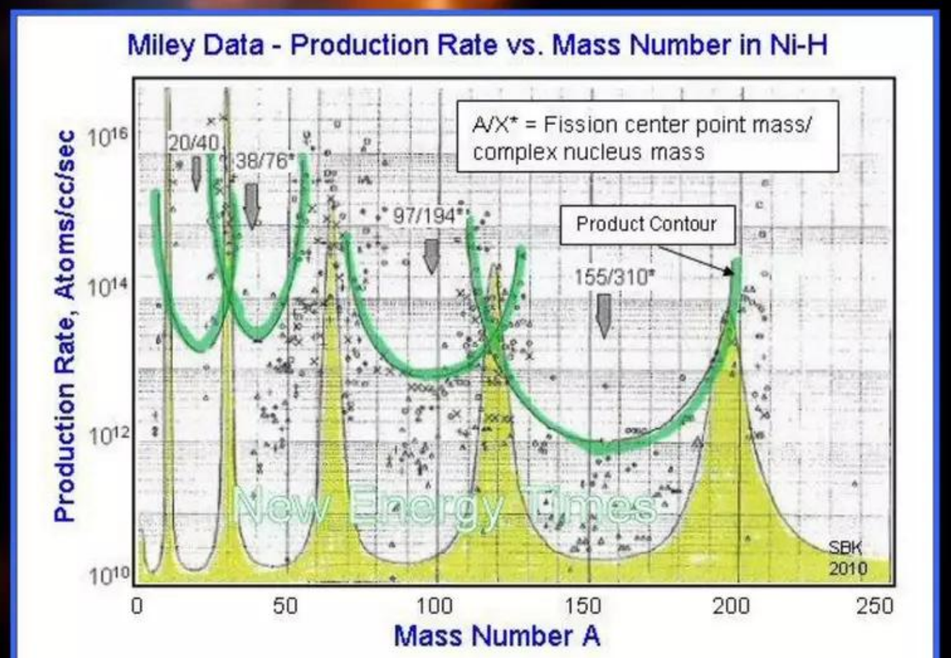
Nickel-cathode electrolytic cells produced star-like LENR products in two weeks

Composite image: expanding supernova remnant G1.9+0.33in local galaxy credit - NASA Chandra X-ray Observatory (2007) and NRAO VLA (1985)

Stars are not mandatory for nucleosynthesis:

- ✓ *Ca.* 1996 Miley (Univ. of Illinois) and Mizuno (Hokkaido Univ.) both reported experimental results with current-driven aqueous H_2O and D_2O electrolytic cells in which essentially the same very complex 5-peak mass spectrum of LENR transmutation products was observed via mass spec after ~two weeks of operation
- ✓ At the time, these results were considered to be inexplicable by any extant theory of LENRs
- ✓ In 2006, Widom and Larsen finally explained this very anomalous data with an absorption model for ultra low momentum LENR neutrons on nuclei; excellent agreement between W-L model's predictions and data shown to right

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



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*

LENRs and the Future of Energy

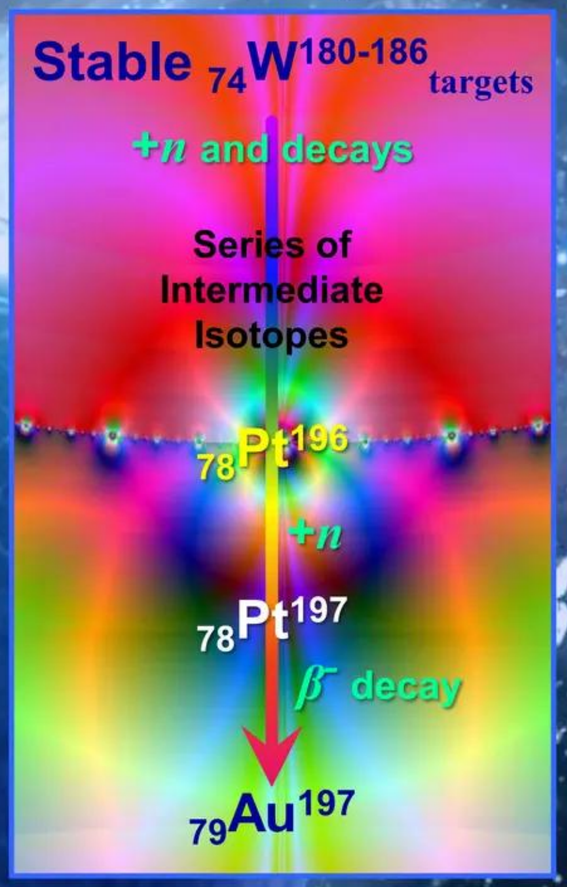
Astrophysicists believe Gold is naturally created in stars

Gold can be created in labs on earth; Nagaoka first achieved it in 1925

Unfortunately many did not believe his peer-reviewed paper published in *Nature*

- ✓ In 1925, Prof. Hantaro Nagaoka, one of most famous physicists in Japan at that time, published a refereed report in *Nature* claiming visible Gold (Au) had been produced during high-current electric discharges between Tungsten (W) metal electrodes that were immersed in a bath of hydrocarbon transformer oil
- ✓ Although paper was peer-reviewed and Nagaoka pleaded with other researchers to attempt to repeat his team's experiments, no one did so anywhere in world
- ✓ In 2012, Mitsubishi Heavy Industries (Japan) finally confirmed Nagaoka's neutron-catalyzed transmutation pathway from Tungsten to Platinum and to Gold using Mitsubishi's novel Deuterium gas permeation method; announced result at American Nuclear Society meeting

LENRs transmute Tungsten into Gold



Neutron-catalyzed transmutations

"Neutron starbursts can forge gold"
Simon Redfern, BBC News, July 18, 2013
Source: http://www.bbc.co.uk/news/science-environment-23561153

Artists conception of colliding neutron stars
Credit: Dana Berry, Skyworks Digital Inc.

LENRs and the Future of Energy

Large companies in Japan have LENR R&D programs

Oct. 2013: Toyota confirmed Mitsubishi's earlier transmutation results

Used LENR lab process to transmute stable Cesium targets into Praseodymium

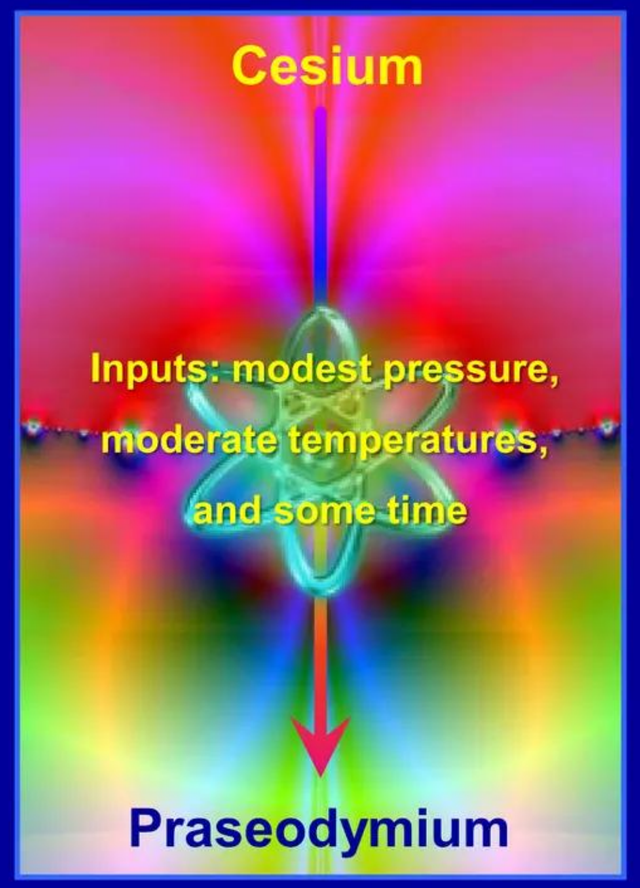
- ✓ In Oct. 2013, Toyota published paper in peer-reviewed *Japanese Journal of Applied Physics* which finally confirmed important experimental results first published by Mitsubishi Heavy Industries in 2002. MHI had claimed transmutation of Cesium into Praseodymium via the forced diffusion of Deuterium gas through thin-film heterostructure containing elemental Palladium using new type of permeation method pioneered by Mitsubishi

- ✓ All these results are both predicted and fully explained by peer-reviewed Widom-Larsen theory of LENRs; neutrons capture on 'target' elements

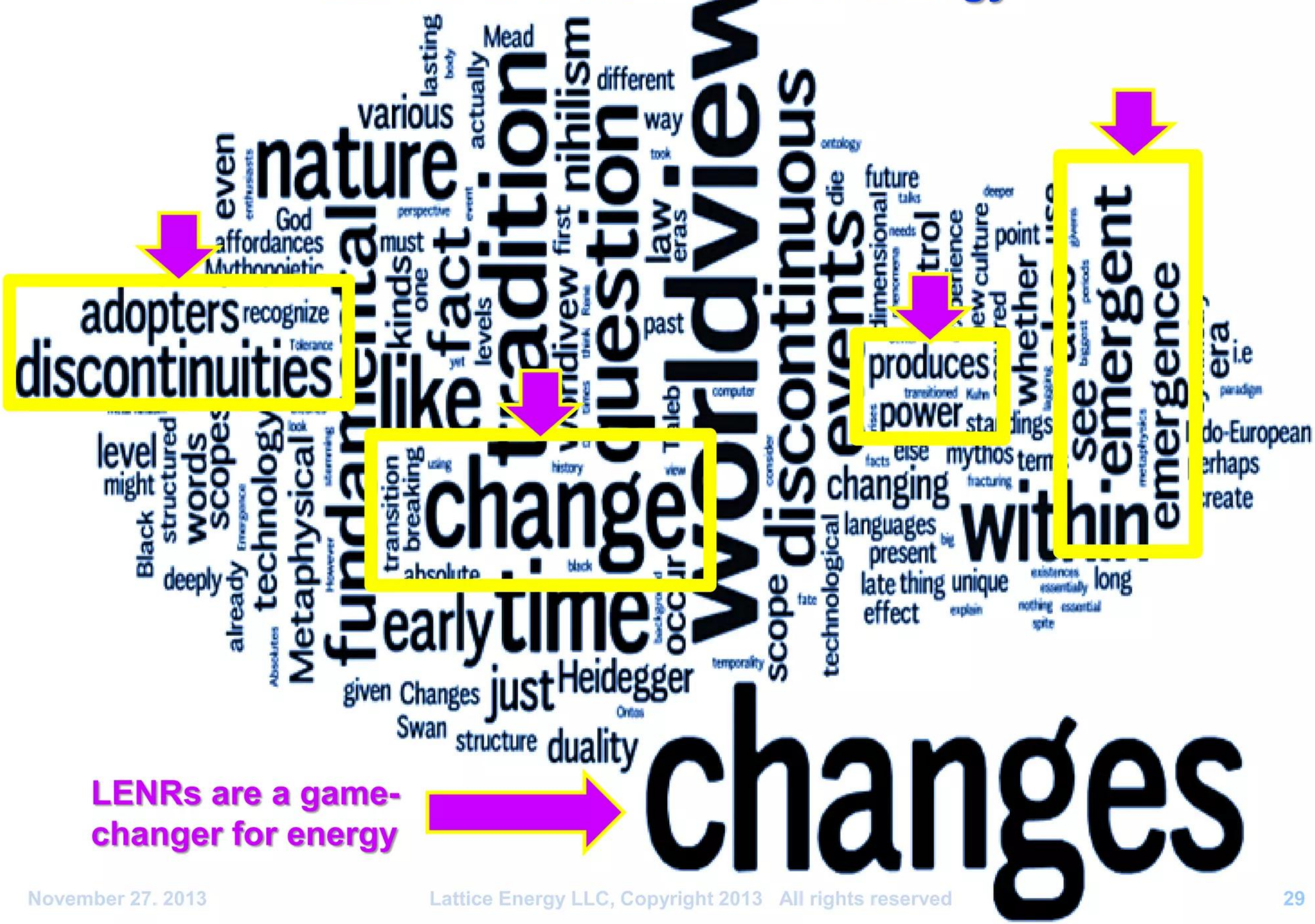
- ✓ While the Mitsubishi permeation method is not suitable for commercial power generation based on LENRs, it has proven to be an excellent laboratory tool for demonstrating that nuclear transmutations can be triggered without using huge macroscopic temperatures and pressures

- ✓ At American Nuclear Society meeting in November 2012, Dr. Yasuhiro Iwamura of Mitsubishi revealed the Toyota Motor Company itself had recently become involved in LENR R&D, along with other large Japanese companies that he declined to name publicly; would not be surprising if their R&D programs aim to eventually replace internal combustion engine

LENR neutron transmutation



LENRs and the Future of Energy



LENRs are a game-changer for energy

LENRs and the Future of Energy

Typical energy releases in power generation technologies

Some LENR processes release > energy than D-T fusion reaction

LENRs better than fission or fusion because no hard radiation emitted

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
H+H Fusion in Stars (1939)	27 MeV		123
D+T Fusion Reactors (1950s)	17. 6 MeV		80
Hydrogen- and Deuterium-based (1989) LENRs	~ 22 MeV (high side)	Nuclear: Weak Interaction	91
	~ 0.1 MeV (low side)		0.45
Blacklight Power's "Hydrinos" (1991)	max 0.02 MeV	?	0.09
Hydrogen Fuel Cells (1838)	0.0002 MeV	Chemical	0.0001
Combustion of Gasoline (1876)	0.0001 MeV		0.00005

Taekwondo | Aikido | Chemical

Evolution of nuclear technology

LENRs and the Future of Energy

Release of nuclear binding energy produces process heat

Several different mechanisms produce clean heat in LENR systems

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

LENRs and the Future of Energy

LENR device manufacturing processes would use nanotech

Commercial production methods would resemble advanced batteries

- ✓ **Over time, LENR devices could ride down the manufacturing experience cost curve and thus drastically reduce cost of LENR-generated power; this would be similar to build-cost reduction and market penetration strategies used by manufacturers of microprocessors, memory chips, PCs, laptops, tablets, smartphones, and batteries**
- ✓ **As product manufacturing experience accumulates and internal build costs are progressively reduced, leverage enormous energy density/longevity advantages of LENRs (>million times larger than chemical); price scaled-up versions of LENR-based systems to drastically undercut price/performance provided by competing thermal sources and chemically-based power generation systems. Strategy can be applied to battery, distributed stationary, mobile, and central station power markets**
- ✓ **Potential to gradually replace internal combustion engines over time; enable reduction of CO_2 emissions and eventual "energy independence" from petroleum**
- ✓ **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 a portfolio of other types of carbon-free energy technologies have the potential to democratize access to clean, affordable CO_2-free energy for every inhabitant of the planet**

LENRs + kaizen → Jihui - the future

Green ultra-high performance power generation systems for important portable, stationary, and mobile applications

Convergence of technologies and change trigger revolution

Jihui (机会) is composed of the Chinese characters: 机 (ji) and 会 (hui)
is somewhat the antonym of weiji (crisis or danger) and has a connotation of chance or opportunity.

Kaizen (改善) is a Japanese concept of "improvement" or "change for the better", refers to philosophy or practices that focus upon continuous improvement of processes in manufacturing, engineering, and business management.

LENRs and the Future of Energy

Additional reading for the technically inclined

LENR nucleosynthesis occurs in Nature as well as the laboratory

Red giant stars, supernovae, fission reactors, and weapons are not required

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

- ✓ **Catalytic converters of cars and trucks during normal vehicular operation**
  http://www.slideshare.net/lewisglarsen/lattice-energy-llc-len-rs-in-catalytic-convertersjune-25-2010
- ✓ **Ordinary atmospheric lightning discharges**
  http://www.slideshare.net/lewisglarsen/audio-larsenelectroweak-neutron-production-and-capture-in-lightning-dischargesans-san-diego-nov-14-2012
- ✓ **Industrial coking ovens during normal operation of pyrolysis processes (Slides #46 - 48)**
  http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewpahs-and-lenrsnov-25-2009
- ✓ **"Water trees" that can form spontaneously in XLPE electric power cables (Slides #49 - 54)**
  http://www.slideshare.net/lewisglarsen/cfakepathlattice-energy-llc-len-rs-in-liion-battery-firesjuly-16-2010
- ✓ **LENRs appear to be causing field-failure problems and fires in Lithium-based batteries:**
  http://www.slideshare.net/lewisglarsen/lattice-energy-llc-increased-energy-densities-drive-convergence-of-batteries-and-lenrssept-6-2013

LENRs and the Future of Energy

Additional reading for the technically inclined

Toyota confirms nuclear transmutations under modest temperatures/pressures:

"Toyota confirmed Mitsubishi's LENR transmutation results --- Successfully transmuted stable Cesium into stable Praseodymium"
Lewis Larsen, Lattice Energy LLC, October 31, 2013 [100 slides + TOC]

http://www.slideshare.net/lewisglarsen/lattice-energy-llc-toyota-confirms-mitsubishi-transmutation-of-cs-to-proct-31-2013

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

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

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

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

"Index to key concepts and documents" v. #15
L. Larsen, Lattice Energy LLC, May 28, 2013 [108 slides] Updated and revised through December 4, 2013

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

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

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

Stated during a media interview (2000)