Lattice Energy LLC

LENRs → Big Bang elements: Deuterium, He, Li, Be

Condensed matter LENRs mimic Big Bang nuclear reactions

No superhot fusion: neutron captures & decays produce same products

Herein we show how ultralow energy neutron reactions in condensed matter (LENRs) under moderate macrophysical conditions can produce same primordial elements as Big Bang nucleosynthesis as well as others across the entire Periodic Table

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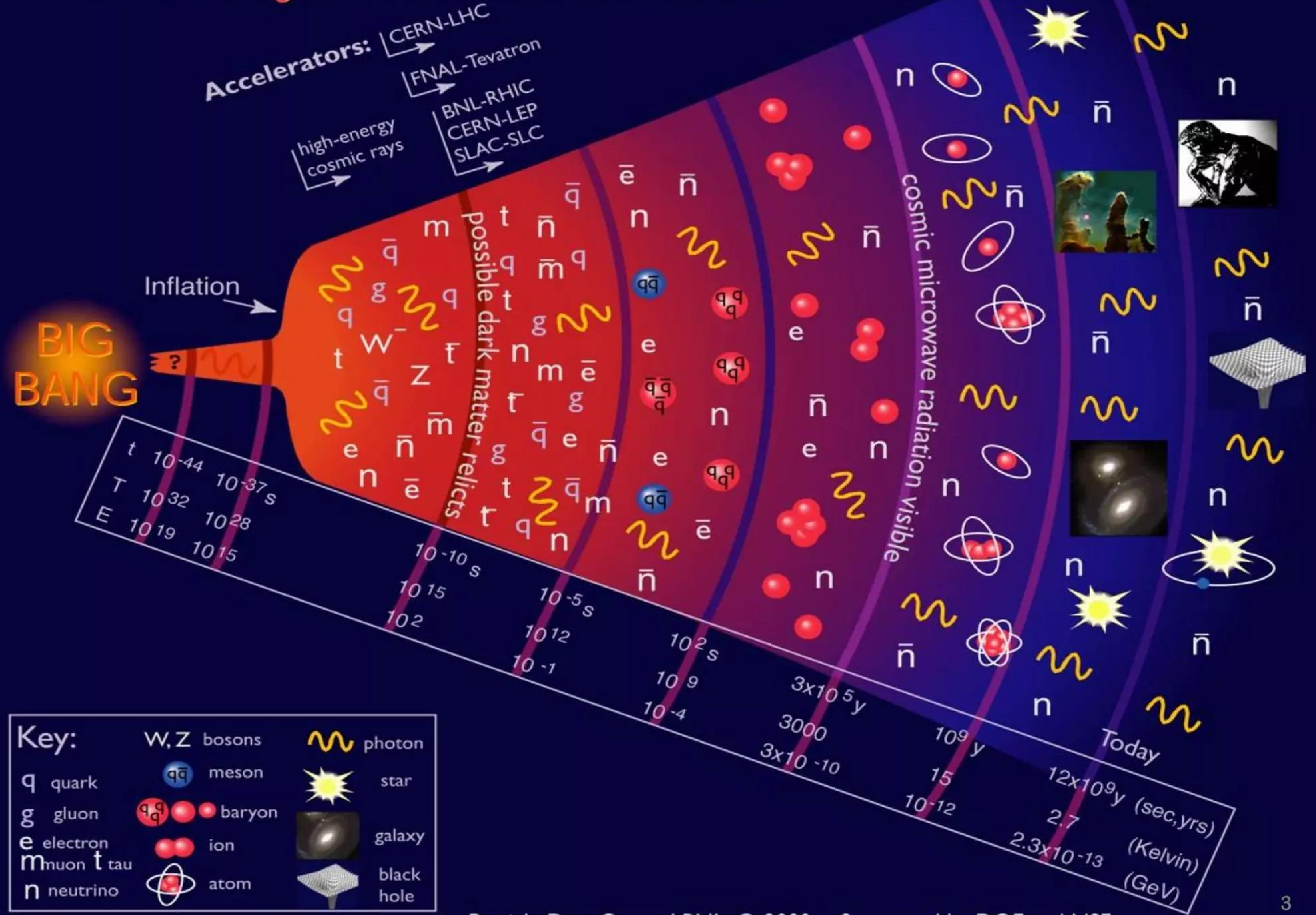
History of the Universe



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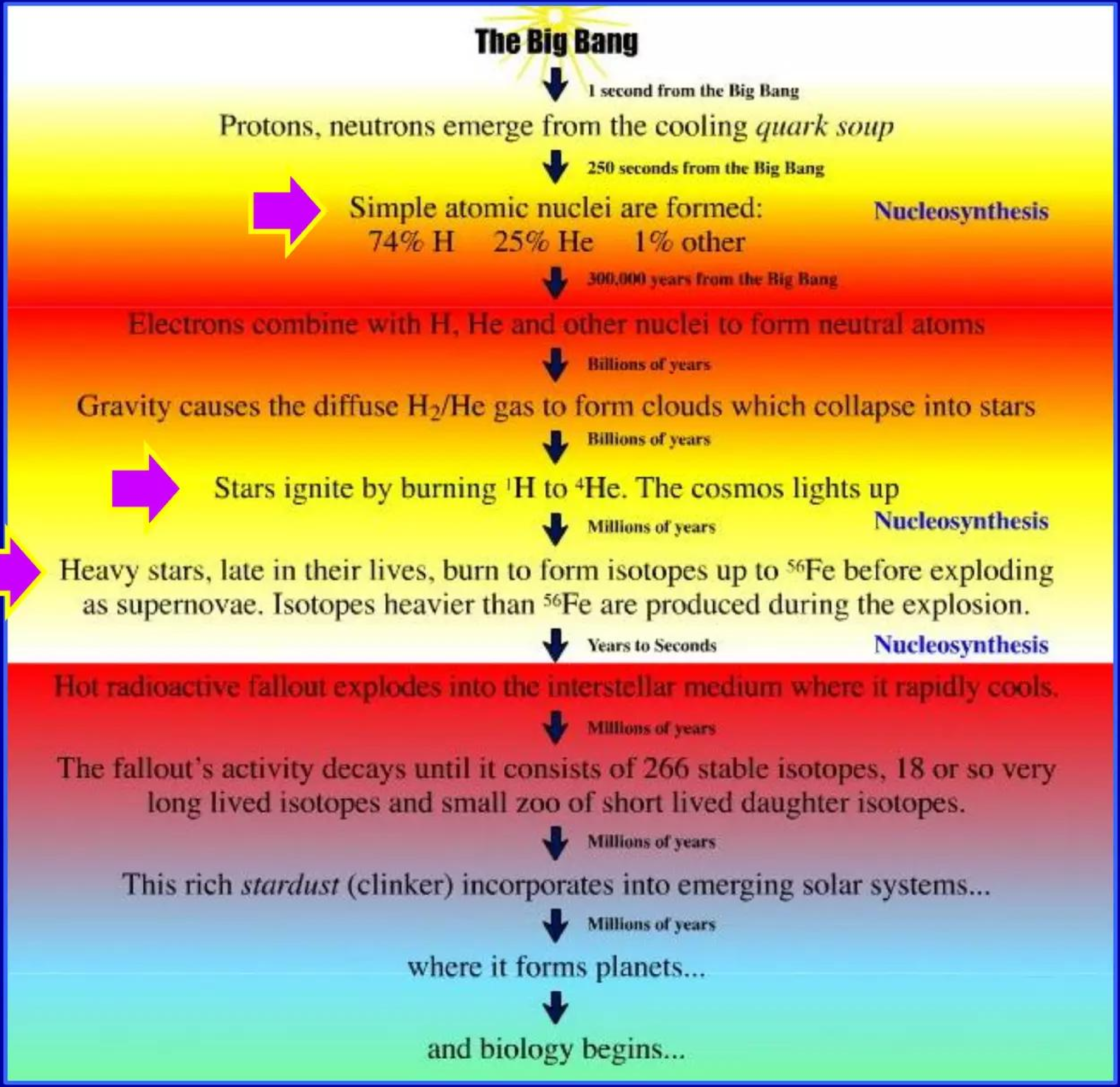
Present astrophysical paradigm about nucleosynthesis



The Big Bang

1 second from the Big Bang

Protons, neutrons emerge from the cooling *quark soup*

250 seconds from the Big Bang

Simple atomic nuclei are formed:
74% H 25% He 1% other

Nucleosynthesis

300,000 years from the Big Bang

Electrons combine with H, He and other nuclei to form neutral atoms

Billions of years

Gravity causes the diffuse H_2/He gas to form clouds which collapse into stars

Billions of years

Stars ignite by burning ^1H to ^4He. The cosmos lights up

Millions of years

Nucleosynthesis

Heavy stars, late in their lives, burn to form isotopes up to ^{56}Fe before exploding as supernovae. Isotopes heavier than ^{56}Fe are produced during the explosion.

Years to Seconds

Nucleosynthesis

Hot radioactive fallout explodes into the interstellar medium where it rapidly cools.

Millions of years

The fallout's activity decays until it consists of 266 stable isotopes, 18 or so very long lived isotopes and small zoo of short lived daughter isotopes.

Millions of years

This rich *stardust* (clinker) incorporates into emerging solar systems...

Millions of years

where it forms planets...

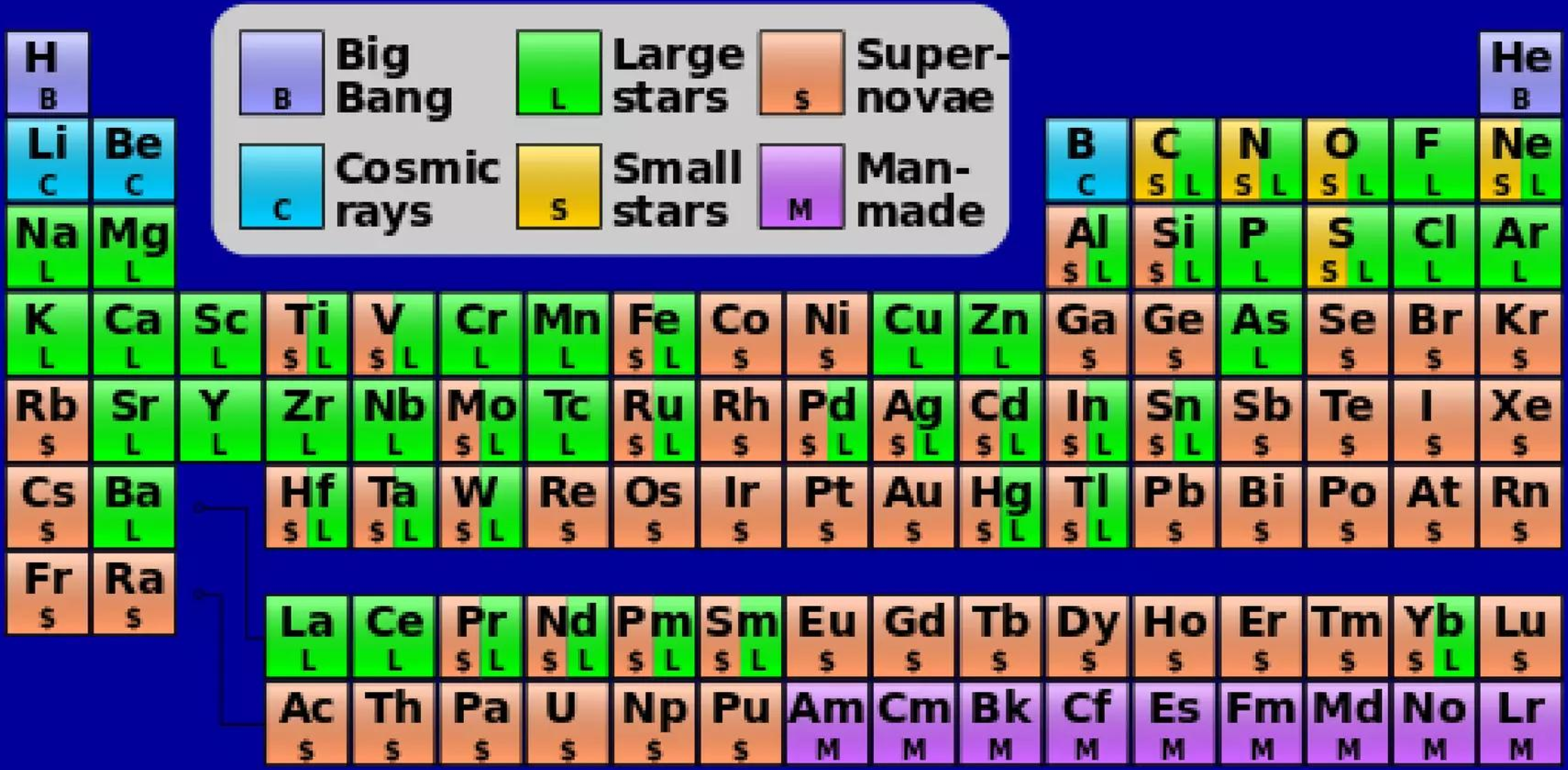
and biology begins...

http://www.meta-synthesis.com/webbook/32_n-synth/nucleosynthesis.html

Old paradigm: stars create most elements in Periodic Table

Big Bang and cosmic ray spallation produce all the remaining elements

r- & s-processes produce all elements not created by Big Bang, CRs, or spallation



B Big Bang
L Large stars
s Super-novae
C Cosmic rays
S Small stars
M Man-made

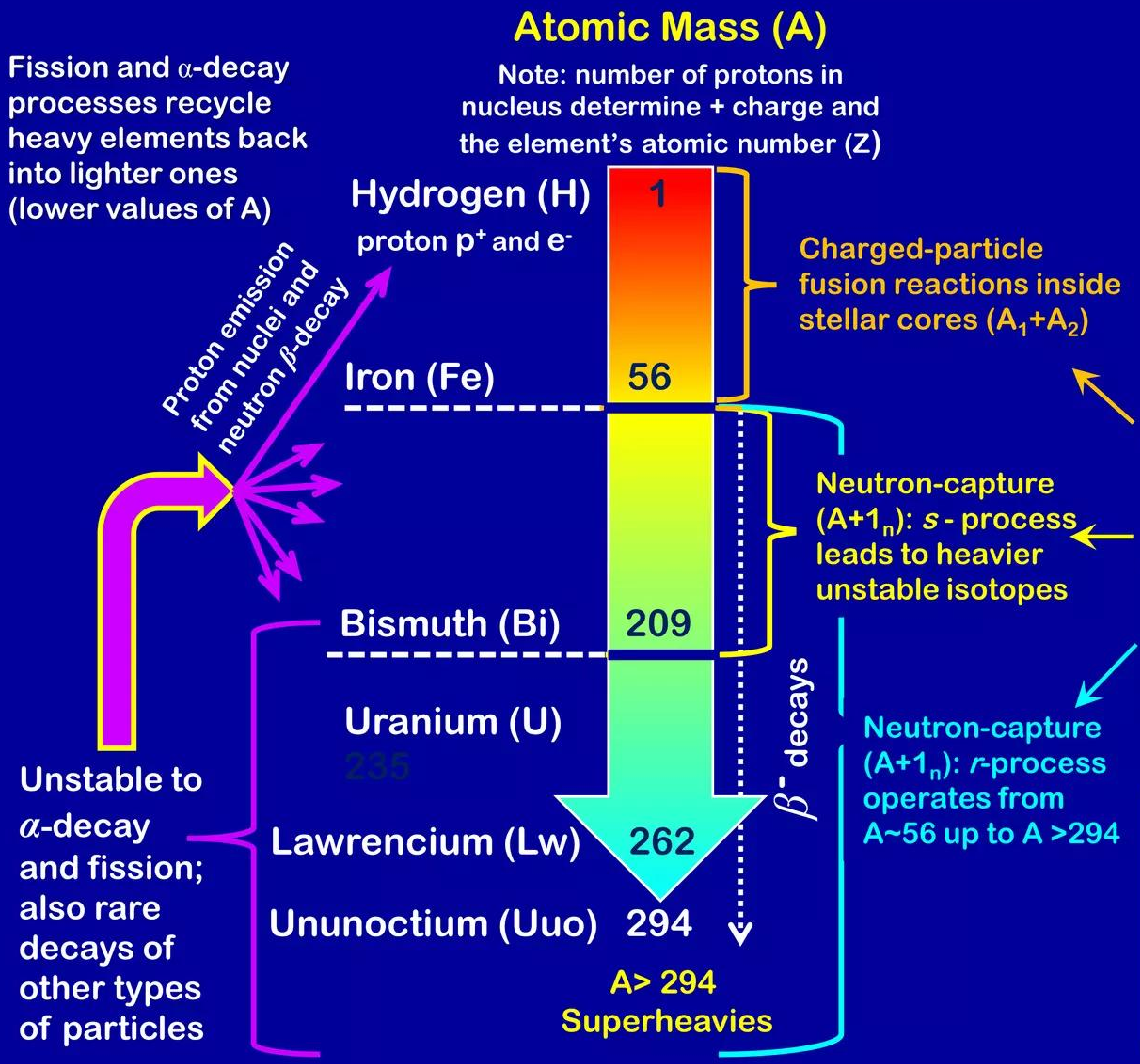
H B																	He B
Li C	Be C											B C	C S L	N S L	O S L	F L	Ne S L
Na L	Mg L											Al s L	Si s L	P L	S S L	Cl L	Ar L
K L	Ca L	Sc L	Ti s L	V s L	Cr L	Mn L	Fe s L	Co s	Ni s	Cu L	Zn L	Ga s	Ge s	As L	Se s	Br s	Kr s
Rb s	Sr L	Y L	Zr L	Nb L	Mo s L	Tc L	Ru s L	Rh s	Pd s L	Ag s L	Cd s L	In s L	Sn s L	Sb s	Te s	I s	Xe s
Cs s	Ba L		Hf s L	Ta s L	W s L	Re s	Os s	Ir s	Pt s	Au s	Hg s L	Tl s L	Pb s	Bi s	Po s	At s	Rn s
Fr s	Ra s																
			La L	Ce L	Pr s L	Nd s L	Pm s L	Sm s L	Eu s	Gd s	Tb s	Dy s	Ho s	Er s	Tm s	Yb s L	Lu s
			Ac s	Th s	Pa s	U s	Np s	Pu s	Am M	Cm M	Bk M	Cf M	Es M	Fm M	Md M	No M	Lr M

Credit: Cmglee via Wikipedia

Cosmic nucleosynthetic cycle in terms of atomic mass A

Fusion up to Fe then neutron capture processes to reach superheavies

Present dominant paradigm in astrophysics and cosmology; LENRs are omitted



Atomic Mass (A)

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

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

Proton emission from nuclei and neutron β-decay

Hydrogen (H) 1

proton p^+ and e^-

Iron (Fe) 56

Bismuth (Bi) 209

Uranium (U) 235

Lawrencium (Lw) 262

Ununoctium (Uuo) 294

A> 294 Superheavies

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

β^- decays

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

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

Neutron-capture ($A+1_n$): *r*-process operates from A~56 up to A >294

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 118 recognized elements (heaviest is Ununoctium Uuo: Z = 118, A = 294, H.L. = ~.89 msec) and > 3,000 known stable and unstable isotopes

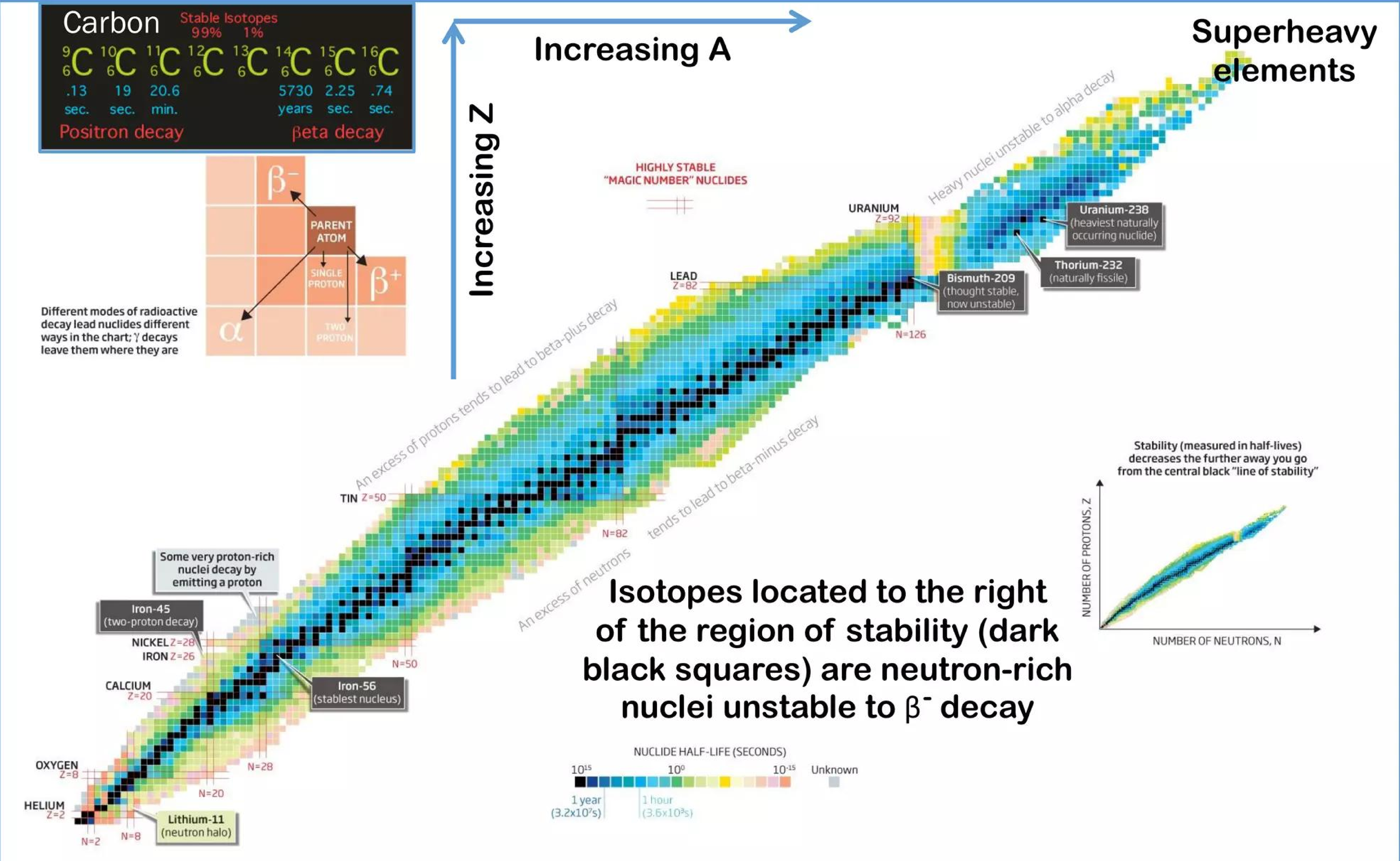
Charged-particle fusion reactions

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

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 different element; value of A = ~same

118 elements: nuclear landscape has 3,000$^+$ known isotopes



Increasing A

Increasing Z

Superheavy elements

Isotopes located to the right of the region of stability (dark black squares) are neutron-rich nuclei unstable to β⁻ decay

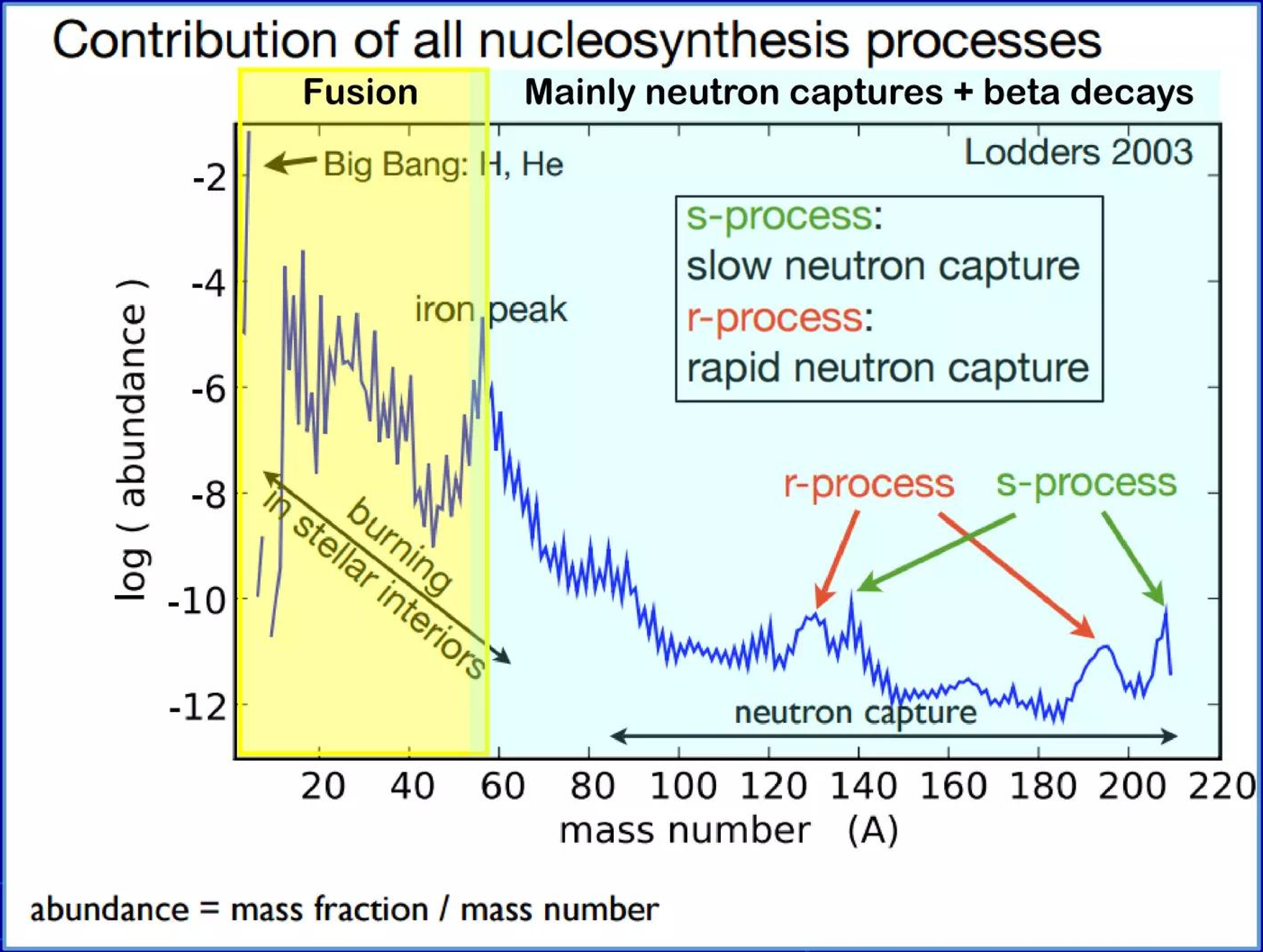
Hydrogen

Adapted from source - credit: *New Scientist* magazine

Present astrophysical paradigm about nucleosynthesis

Depending on mass, Big Bang, fusion, s-/r-processes create elements

Fusion, s-/r-processes happen in stars - little nucleosynthesis occurs elsewhere

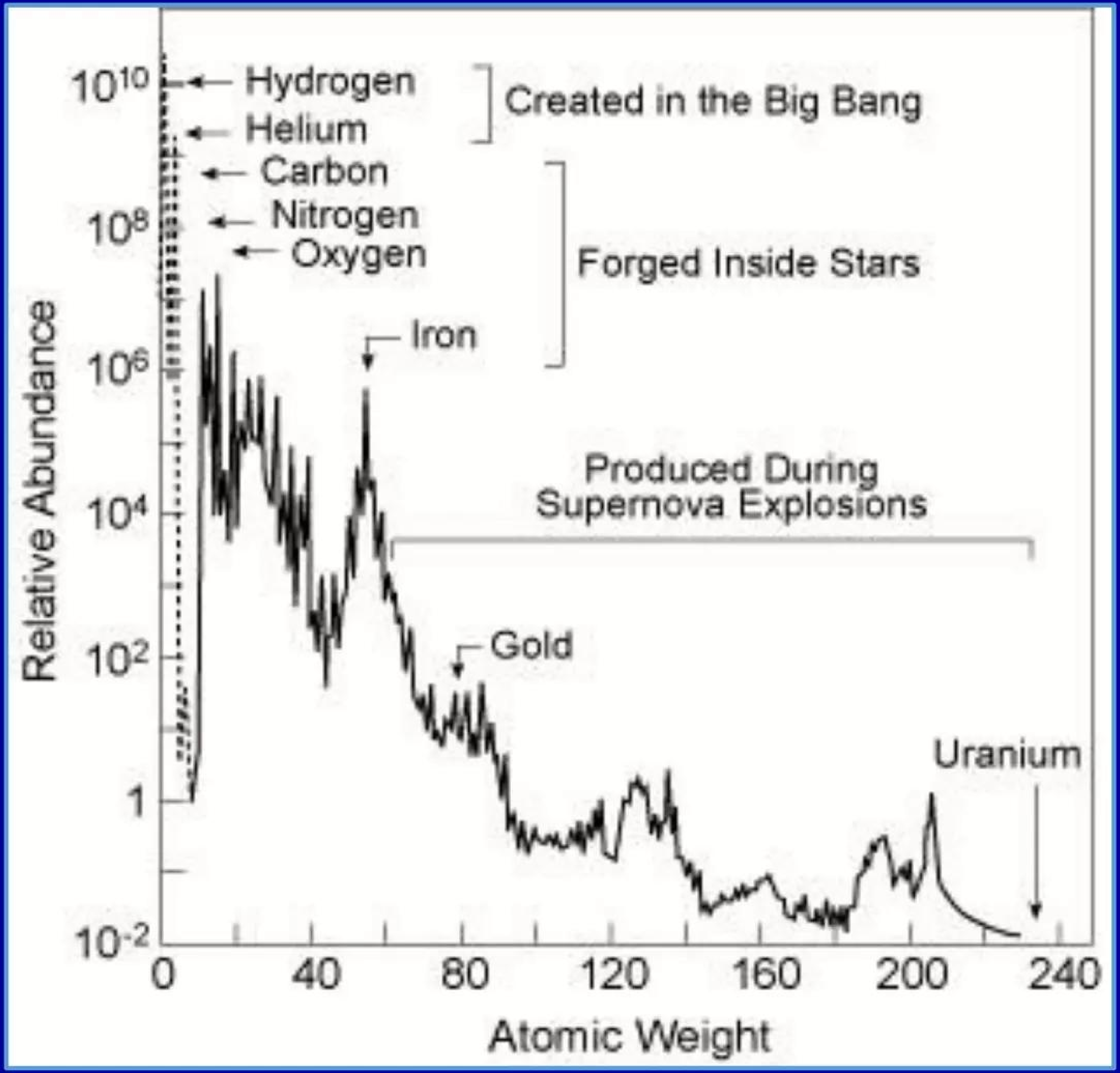


Adapted after Lodders (2003)

Present astrophysical paradigm about nucleosynthesis

Many heavy elements beyond Iron (Fe) made in supernova explosions

Unlike Big Bang, r-/s processes: LENRs can create elements from A= 2 to heaviest

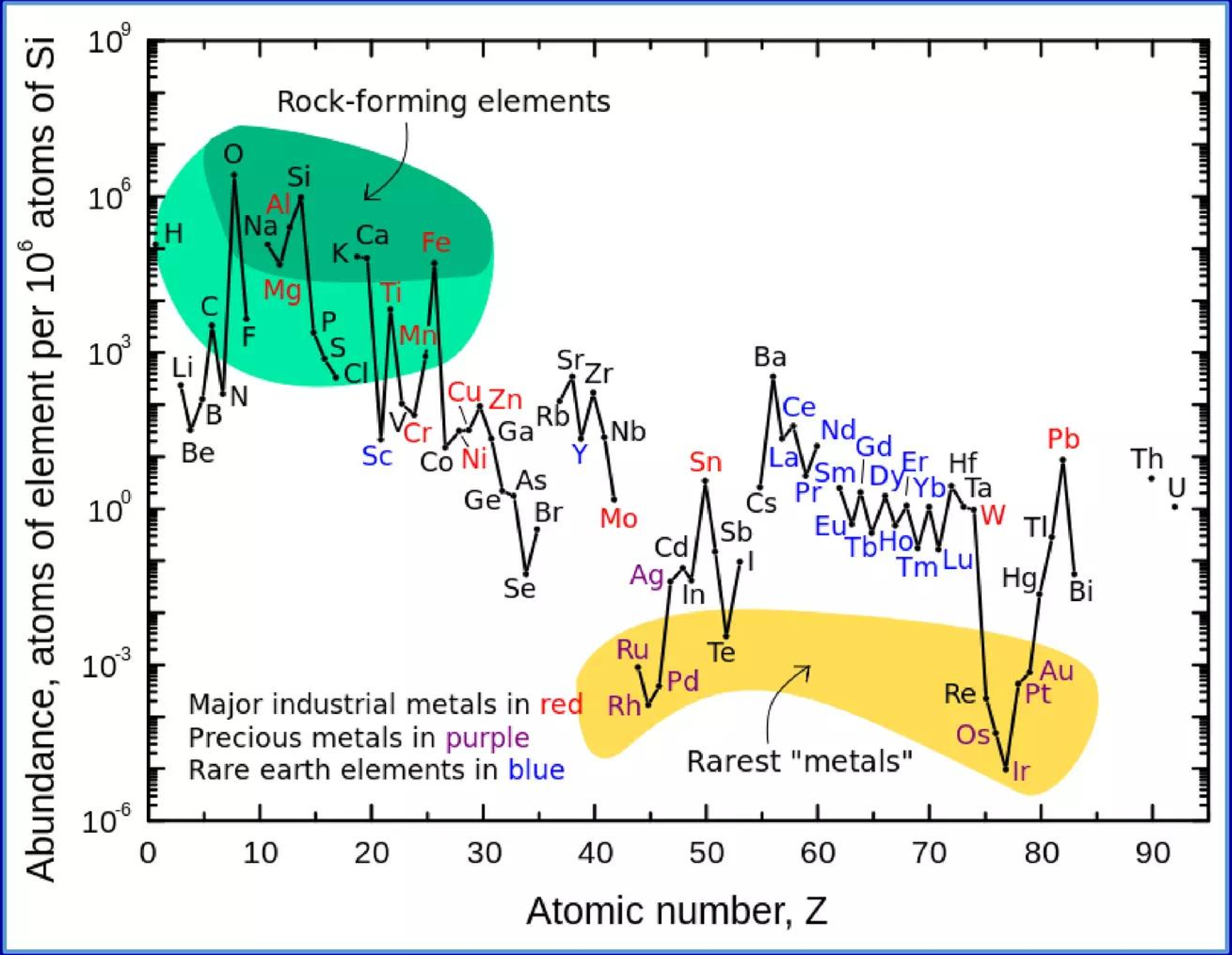


Credit : NASA

Relative abundances of chemical elements in Earth's crust

Many of these elements were verifiably produced in LENR experiments

Miley et al. (1996) reported such results; Mitsubishi HI has transmuted rare earths

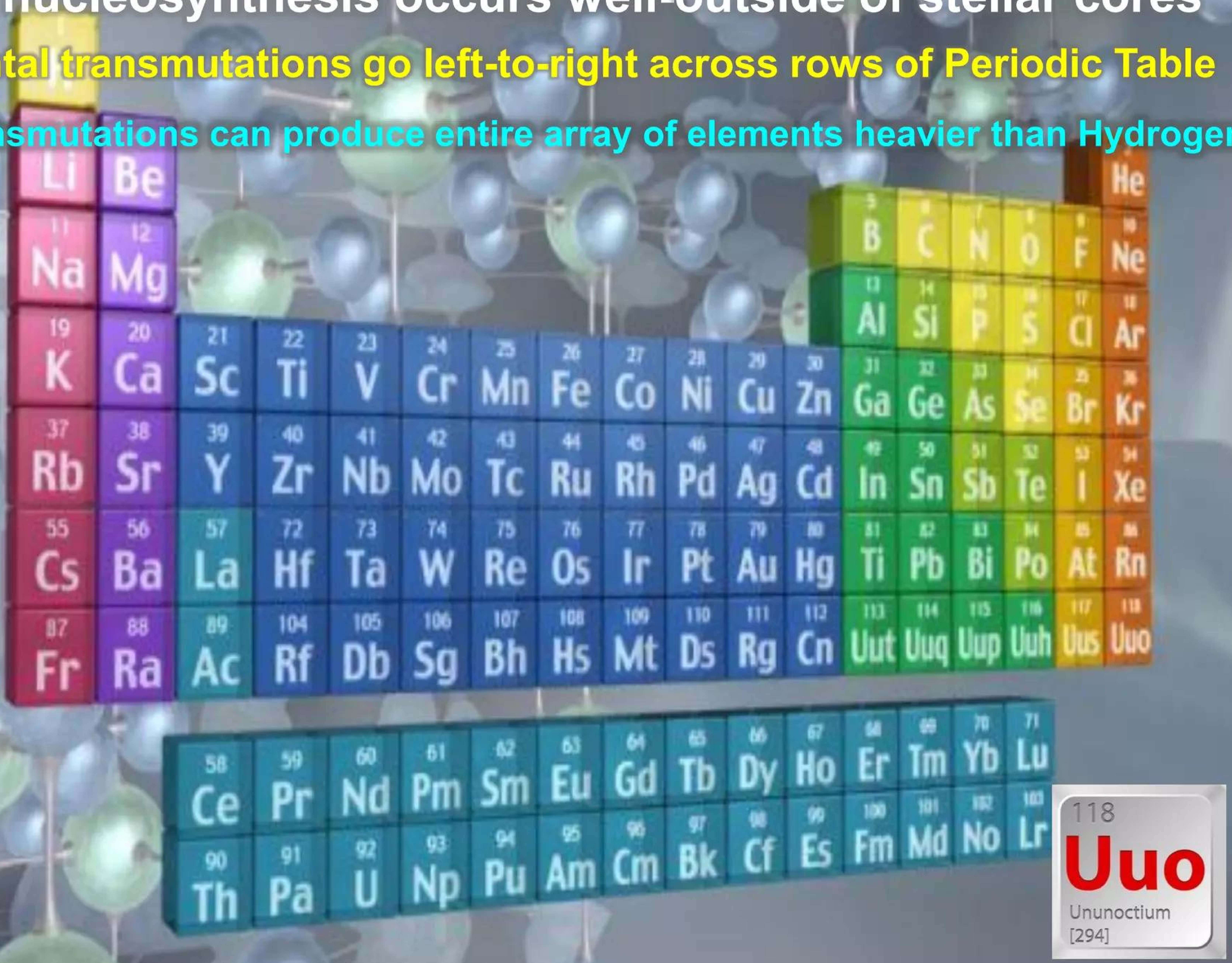


Credit: "Elemental abundances" by Gordon B. Haxel, Sara Boore, and Susan Mayfield from USGS
Vectorized by User: michbich

New: nucleosynthesis occurs well-outside of stellar cores

Elemental transmutations go left-to-right across rows of Periodic Table

LENR transmutations can produce entire array of elements heavier than Hydrogen



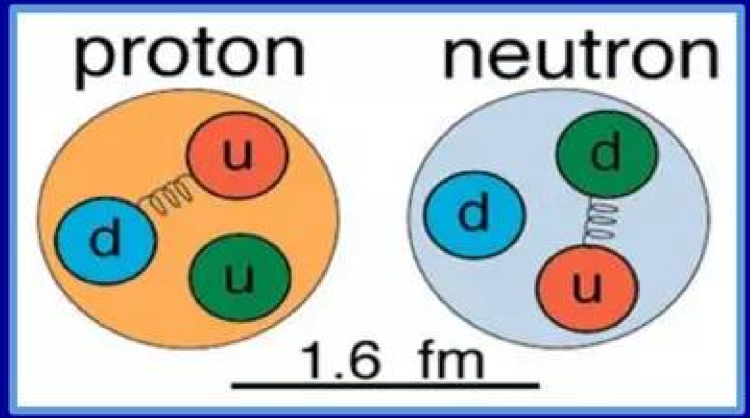
© Corbis

Prior to W-L theory e + p reaction occurs just in supernovas

Many-body collective effects + entanglement allow it in condensed matter

W-L's first-principles rate calculations show that 10^{12} - 10^{14} cm^2/sec are achievable

- ✓ Prior to advent of the Widom-Larsen theory, astrophysicists believed that neutronization (direct e^- + p^+ reaction) *only* occurred deep in stellar cores during supernova explosions
- ✓ No "new physics" in Widom-Larsen theory: we simply integrated many-body collective and quantum mechanical effects with modern electroweak theory under the overall umbrella of the Standard Model; vast body of already-published experimental data supports theory
- ✓ Without many-body collective effects plus condensed matter quantum mechanical entanglement, electroweak reactions could *never* occur at substantial rates at moderate temperatures/pressures in chemical cells



Neutronization during supernova explosion

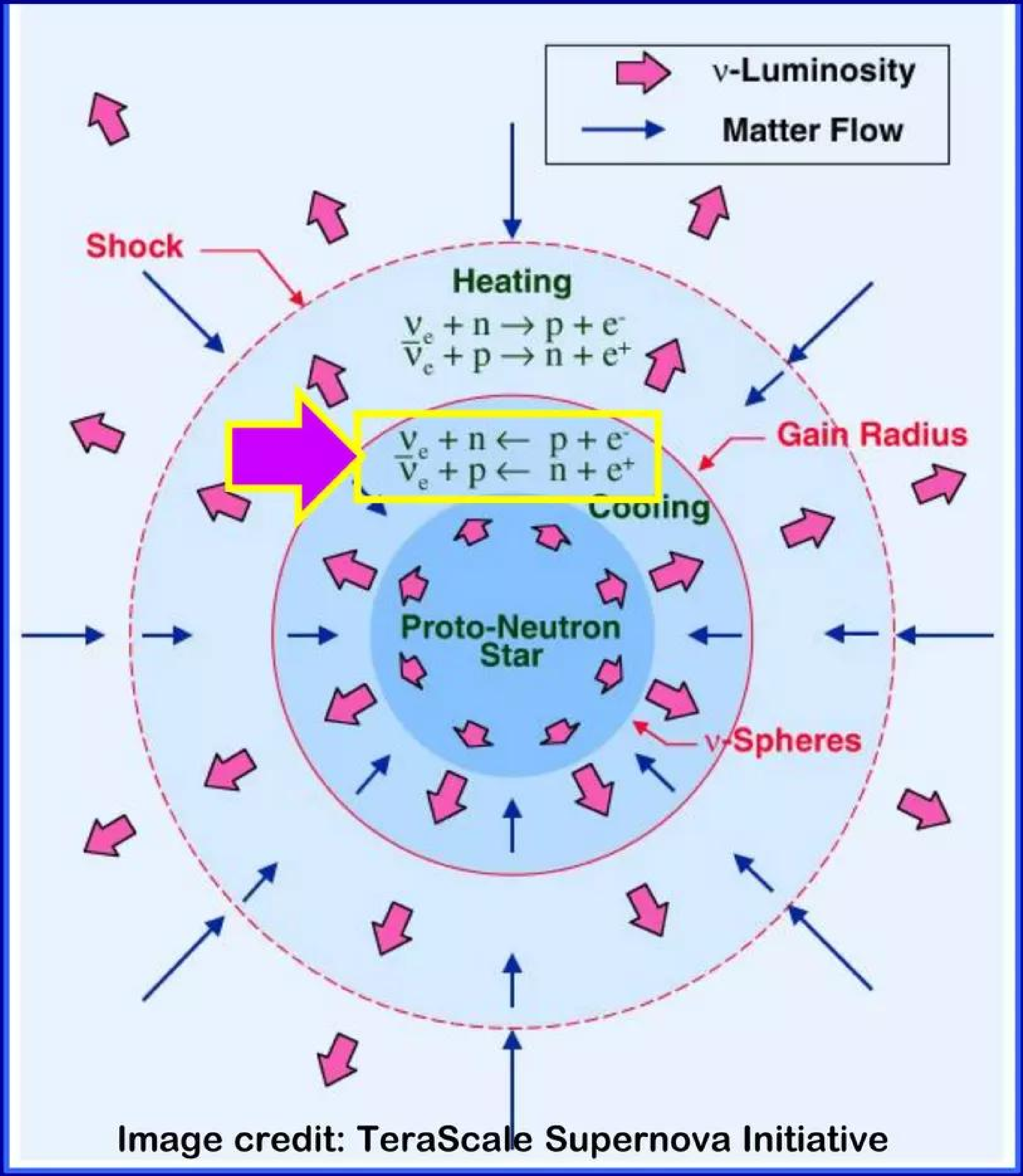


Image credit: TeraScale Supernova Initiative

Key reactions in Widom-Larsen-Srivastava theory

Many-body collective processes produce neutrons and other particles

Neutrons are captured by elements which trigger nuclear transmutation reactions

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

Collective many-body processes require external input energy

$$e^{-*} + p^{+} \rightarrow n + v_e$$

Electric fields dominate

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

Magnetic fields dominate

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

Transmutation of elements and nucleosynthesis outside of stellar cores:

Neutron capture-driven LENR transmutation reactions

$$n + (\mathrm{Z, A}) \rightarrow (\mathrm{Z, A+1})$$

Neutron capture

$$(\mathrm{Z, A+1}) \rightarrow (\mathrm{Z + 1, A+1}) + e_{\beta}^{-} + \overline{v}_e$$

Beta-minus decay

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

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

Appropriate input energy is required to produce neutrons

Electron or ion currents; E-M photon fluxes; organized magnetic fields

Input energy is required to trigger LENRs: 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 $e^{-}* + d^{+} \rightarrow 2\ n$, $e^{-}* + t^{+} \rightarrow 3\ n$ (energy cost = 0.78 MeV/neutron for H; 0.39 for D; 0.26 for T); includes (can combine sources):

- ✓ **Electrical currents** - i.e., an electron 'beam' of one sort or another can serve as a source of input energy for producing neutrons via $e + p$ electroweak reaction
- ✓ **Ion currents -** passing across a surface or an interface where 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 for inputting energy is an ion flux caused by imposing a modest pressure gradient (Iwamura *et al.* 2002)
- ✓ **Incoherent and coherent electromagnetic (E-M) photon fluxes -** can be incoherent E-M radiation found in resonant electromagnetic cavities; with proper momentum coupling, SP electrons can also be directly energized with coherent laser beams emitting photons at appropriate resonant wavelengths
- ✓ **Organized magnetic fields with cylindrical geometries -** many-body collective magnetic LENR regime with direct acceleration of particles operates at very high electron/proton currents; includes organized and so-called dusty plasmas; scales-up to stellar flux tubes on stars with dimensions measured in kilometers

Neutron-driven LENRs induce transmutations of elements

Widom-Larsen theory explains 100 years of anomalous experimental data

Effects were not attributed to nuclear process because hard radiation was absent

- ✓ **Widom-Larsen theory explains LENRs unique absence of hard, deadly MeV-energy neutron and gamma radiation**
- ✓ Published in peer-reviewed physics journals: *European Physical Journal C* and *Pramana - Journal of Physics*
- ✓ **Sheds light on 100 years of anomalous experimental data.** Scientists have been reporting various LENR effects in experiments since ~1900 but didn't attribute causation to nuclear processes due to the absence of hard radiation
- ✓ **Electroweak reactions are relatively simple:** heavy-mass electrons react directly with protons (hydrogen nucleus) to create neutrons and benign electron neutrino ν_e photons
- ✓ Safe ultra-low energy neutrons are potent nuclear particle 'matches' that induce transmutations of elements; trigger release of stored nuclear binding energy from nuclei. **Very high capture cross-sections for ULM neutrons on truly vast numbers of stable and unstable isotopes makes it an ideal energy technology because fuel possibilities are enormous**

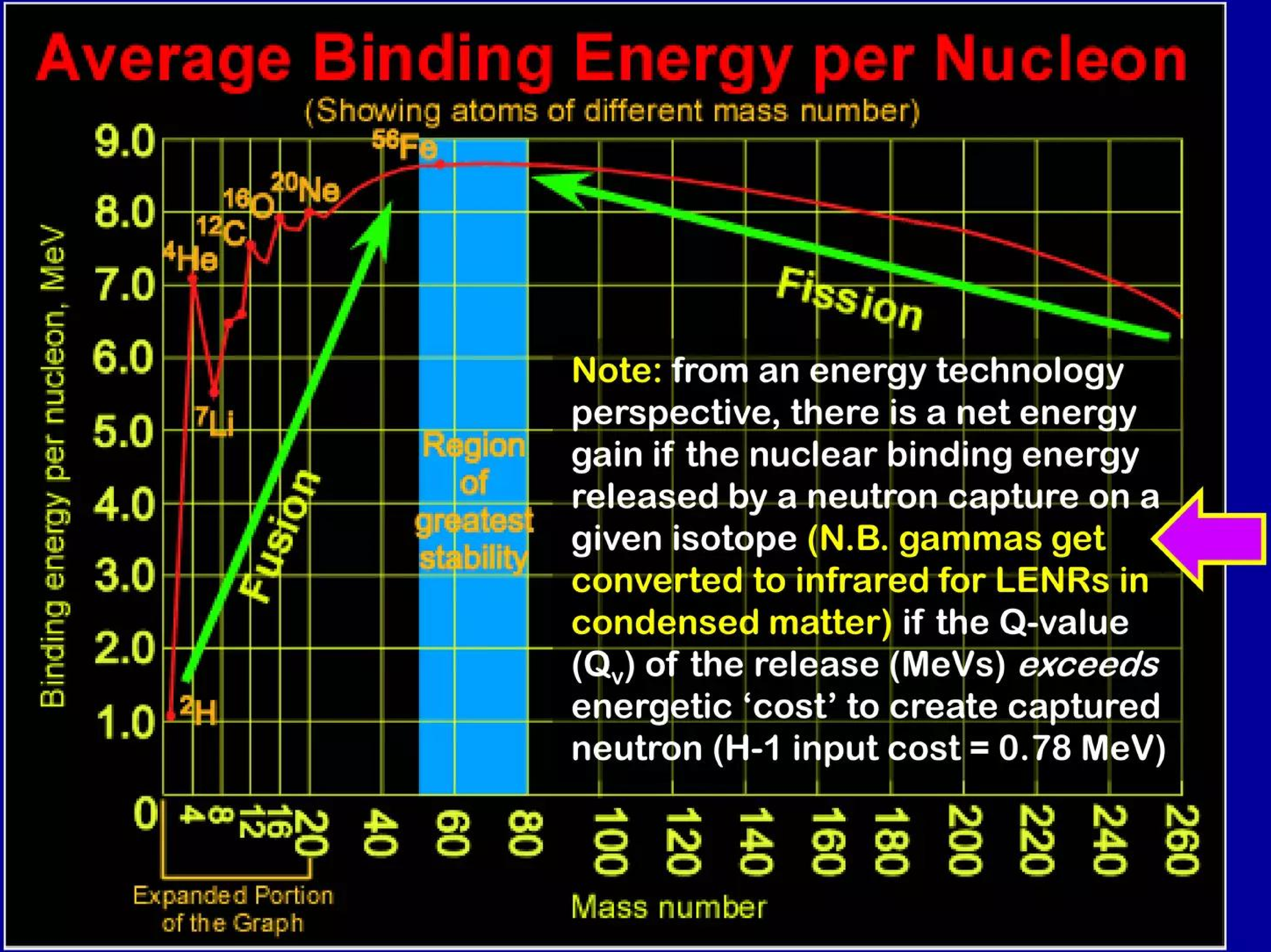
Neutrons are akin to safety matches

Trigger release of nuclear binding energy when captured by many isotopes

Average binding energy per nucleon from A = 2 to A = 260

Binding energy/nucleon peaks around Iron (Fe) and then slowly declines

By contrast, neutron captures release binding energy across almost entire range



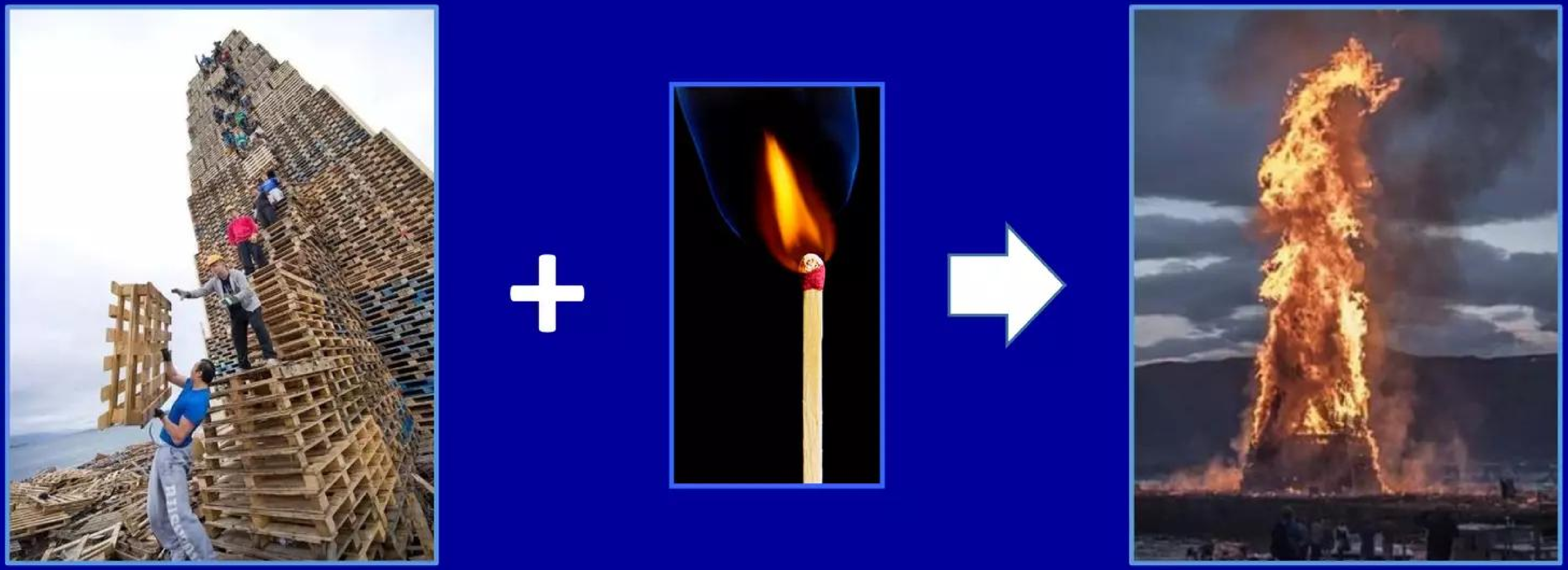
Note: from an energy technology perspective, there is a net energy gain if the nuclear binding energy released by a neutron capture on a given isotope (N.B. gammas get converted to infrared for LENRs in condensed matter) if the Q-value (Q_v) of the release (MeVs) *exceeds* energetic 'cost' to create captured neutron (H-1 input cost = 0.78 MeV)

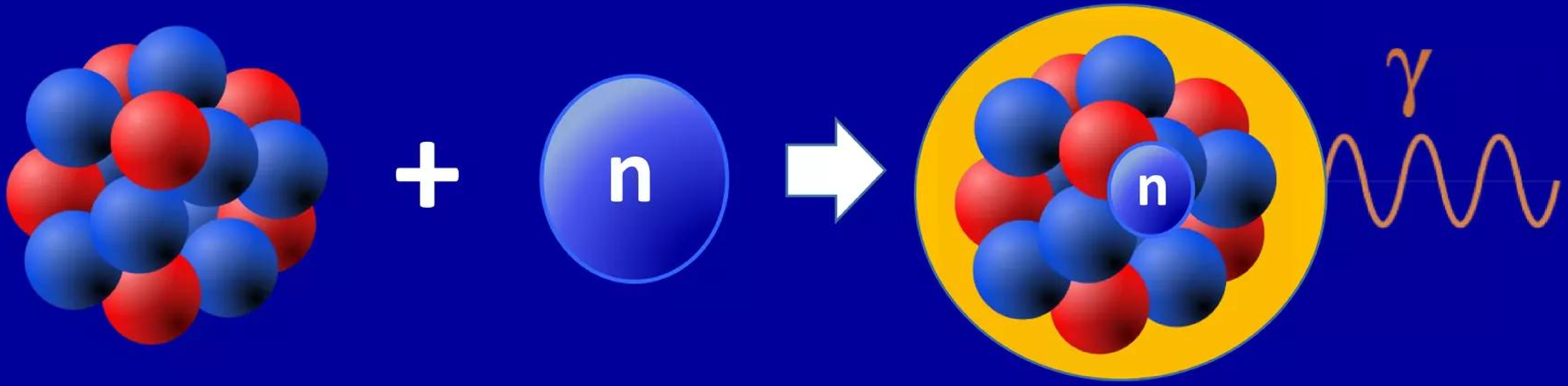
In theory a single match could ignite wood pile 131’ high

Match triggers release of chemical thermal energy via burning of wood

Neutrons trigger releases of nuclear binding energy via being captured by atoms

http://www.viralnova.com/huge-pallet-bonfire-norway/





Target atomic nucleus **ULM neutron** **Excited nucleus emits gamma**

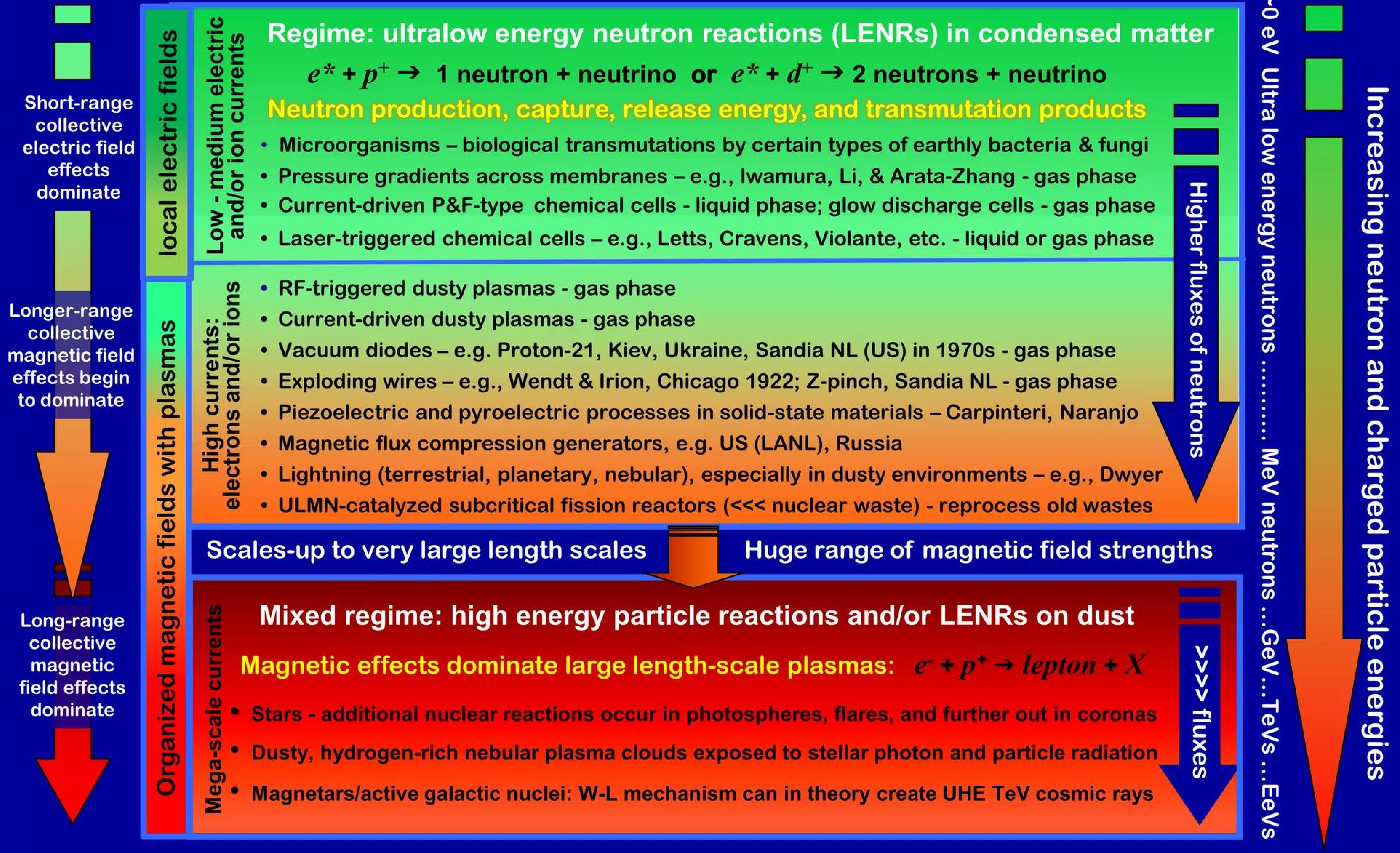
LENRs operate like r- and s-process in condensed matter

Electroweak $e^- + p^+$ reactions can occur in domains besides supernovae

- ✓ In our *European Physical Journal C - Particles and Fields* paper (2006) we explained how many-body collective quantum effects in condensed matter can produce ultralow energy neutrons via the electroweak $e^- + p^+$ reaction in tabletop apparatus under very modest macrophysical conditions. Results of subsequent neutron-catalyzed transmutation reactions resemble astrophysical s- and r-processes only at temperatures vastly lower than with stars
- ✓ We next analyzed and explained case of LENR transmutation products observed in high pulsed-current exploding wires with cylindrical geometries; note that collective many-body magnetic effects (B-fields) dominate therein. This case differs from condensed matter chemical cells wherein micron-scale, nuclear-strength local E-fields and local breakdown of Born-Oppenheimer are much more important
- ✓ Once one understands LENRs in magnetically dominated collective systems, lightning discharges are conceptually like a big exploding wire up in the sky. Moreover, predicted electroweak $e^- + p^+$ reactions inside solar coronal loops and flares is direct extension of the same physics principles

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

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



Short-range collective electric field effects dominate

Longer-range collective magnetic field effects begin to dominate

Long-range collective magnetic field effects dominate

local electric fields

Organized magnetic fields with plasmas

Low - medium electric and/or ion currents

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

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

Neutron production, capture, release energy, and transmutation products

- Microorganisms – biological transmutations by certain types of earthly bacteria & fungi
- Pressure gradients across membranes – e.g., Iwamura, Li, & Arata-Zhang - gas phase
- Current-driven P&F-type chemical cells - liquid phase; glow discharge cells - gas phase
- Laser-triggered chemical cells – e.g., Letts, Cravens, Violante, etc. - liquid or gas phase

High currents: electrons and/or ions

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

Higher fluxes of neutrons

Scales-up to very large length scales

Huge range of magnetic field strengths

Mega-scale currents

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

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

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

>>>> fluxes

~0 eV Ultra low energy neutrons .... MeV neutrons ...GeV...TeVs ...EeVs

Increasing neutron and charged particle energies

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

W-L-S theory and its collective effects extend from LENRs in condensed matter regimes to environments found in high-current exploding wires, e.g., large wire inductors, as well as up to large-length-scale, magnetically dominated regimes that occur in astrophysical systems

Length Scale	Type of System	Electromagnetic Regime	Many-body Collective Phenomena	Comment
Submicron	Certain earthly bacteria and some fungi	Very high, short-range electric fields	Transmutations, high level of gamma shielding	Obtain unavailable trace elements; survive deadly gamma or X-ray radiation
Microns	Hydrogen isotopes on metallic surfaces	Very high, short-range electric fields on solid substrates	Transmutations, high level of gamma shielding, heat, some energetic particles	This regime is useful for small-scale commercial power generation
Microns to many meters	Exploding wires, planetary lightning	Dusty plasmas: mixed high-current and high local magnetic fields	Transmutations, 'leakier' gamma shielding, heat; X-rays up to 10 keV, larger energetic particle fluxes	This regime is useful for large-scale commercial power generation
Many meters to kilometers	Outer layers and atmospheres of stars (flux tubes)	Ideal and dusty plasmas: high mega-currents of electrons, protons, and ions inside large-scale, ordered magnetic structures with substantial internal fields	Energetic charged particles and neutrons (MeVs to EeVs), X-rays, gamma-ray bursts, and ultra-high-energy cosmic rays (TeVs to EeVs)	Provides explanation for heating of solar corona and radioactive isotopes in stellar atmospheres
Up to several AU (distance from earth to Sun)	Neutron stars and active galactic nuclei in vicinity of compact, massive objects (black holes)			Provides mechanism for creating extremely high energy particles in plasma-filled magnetic flux tubes with sufficient field strengths

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

W-L theory: LENRs occur in micron-scale surface regions

Enabled by many-body collective effects and local quantum entanglement

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

2. Born-Oppenheimer approximation breaks down, allowing E-M coupling between Q-M entangled surface plasmon electrons and patch protons; allows application of input energy to create nuclear-strength local electric fields > 10^{11} V/m that will increase effective masses of surface plasmon electrons in such patches

3. Heavy-mass surface plasmon electrons formed in many-body patches can react directly with electromagnetically interacting Hydrogen isotopes; process creates neutrons and neutrinos via many-body collective electroweak reactions, namely:

$$e^{-*}_{sp} + p^{+} \rightarrow n + \nu_e \qquad e^{-*}_{sp} + d^{+} \rightarrow 2n + \nu_e \qquad e^{-*}_{sp} + t^{+} \rightarrow 3n + \nu_e$$

4. Neutrons collectively created in patch have ultra-low kinetic energies and are all absorbed locally by atoms - few neutrons escape into environment; locally produced gammas converted directly into safe infrared photons by unreacted heavy electrons (Lattice patent US# 7,893,414 B2) - no hard gamma emissions

5. Transmutation of elements: formation of μ -scale craters at active sites begins

6. **Neutron production rates in well-performing systems can hit 10^{12} - 10^{14} cm^2/sec**

Collectively produced neutrons have ultra low momentum

Capture cross-sections on nuclei vastly higher than thermalized neutrons

- ✓ Unlike energetic neutrons produced in most nuclear reactions, collectively produced LENR neutrons are effectively standing still at the moment of their creation in condensed matter systems. Since they are thus vastly below thermal energies (i.e., they have ultra low momentum), ULM neutrons have huge DeBroglie wavelengths and commensurately large capture cross-sections on any nearby nuclei; virtually all will be locally absorbed; very few are detectable as free neutrons

- ✓ Q-M DeBroglie wavelength λ of neutrons produced by a condensed matter collective system must be comparable to micron-scale spatial dimensions of many-body proton surface patches in which they were created. Wavelengths of such neutrons can be on the order of $\lambda \approx 3 \times 10^{-3}$ cm or more; ultra low momentum of collectively created LENR neutrons follows directly from DeBroglie relation:

$$p = \frac{h}{\lambda} = \frac{2\pi\hbar}{\lambda} = \frac{\hbar}{\lambdabar}$$

- ✓ For vast majority of stable and unstable isotopes, their neutron capture cross-sections (relative to measurements of cross-sections at thermal energies where v = 2,200 m/sec and the DeBroglie wavelength is ~ 2 Angstroms) are directly related to ~1/v, where v is velocity of a neutron in m/sec. Since v is extraordinarily small for ULM neutrons, their capture cross-sections on atomic nuclei will be proportionately larger. After being collectively created, virtually all ULMNs will be locally absorbed before scattering on lattice atoms can elevate them to thermal kinetic energies; per S. Lamoreaux (Yale) thermalization would require ~0.1 to 0.2 msec (10^{-4} sec.) --- a very long time relative to the typical 10^{-16} - 10^{-19} sec. time-scale of many nuclear reactions

Collectively produced neutrons have ultra low momentum

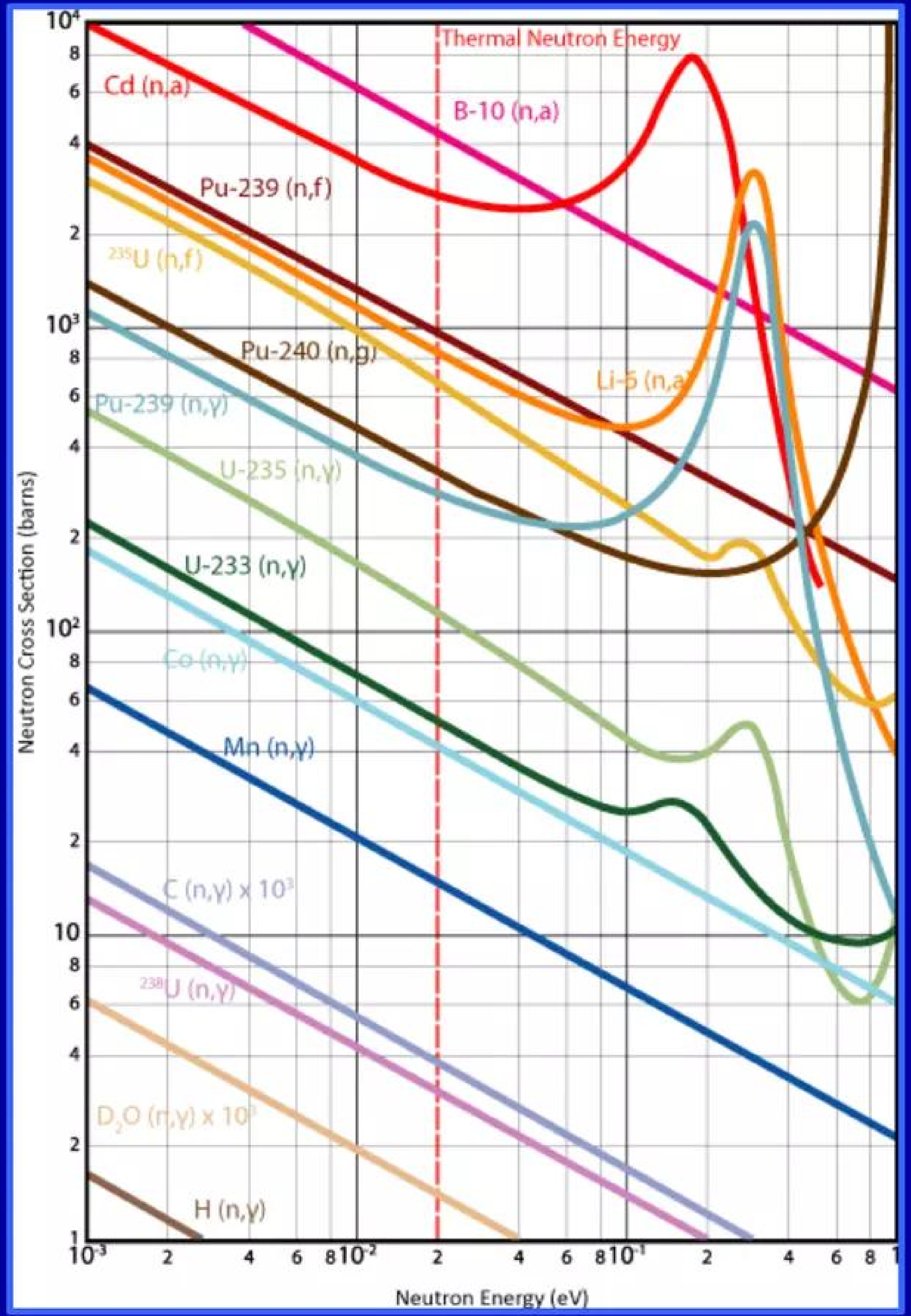
Capture cross-sections on nuclei vastly higher than thermalized neutrons

Detectable fluxes of free neutrons rare in LENR experiments; virtually all captured

- ✓ Overwhelming majority of 3,000+ known isotopes will ~ follow the 1/v rule where v is neutron velocity in m/sec; capture cross-sections will increase roughly linearly with *decreasing* neutron energies
- ✓ So-called “ultra cold” neutrons have kinetic energy of ~300 neV; corresponds to maximum velocity of ~8 m/sec or a minimum DeBroglie quantum mechanical (Q-M) wavelength of 52 nm (0.52 μ)
- ✓ Ultralow momentum LENR neutrons can have DeBroglie Q-M wavelengths perhaps as large as ~ 100+ μ (size of a bacterium for picoseconds); would have proportionately lower velocities in m/sec and way-higher neutron capture cross-sections in barns

Occasionally small, bursty neutron fluxes are seen in certain experiments: these represent only a very tiny % of total LENR neutron production; few of total will be measurable as free, thermal- or even higher-energy neutrons

Neutron capture cross-sections for selected isotopes vs. neutron energy



Source: Wikipedia

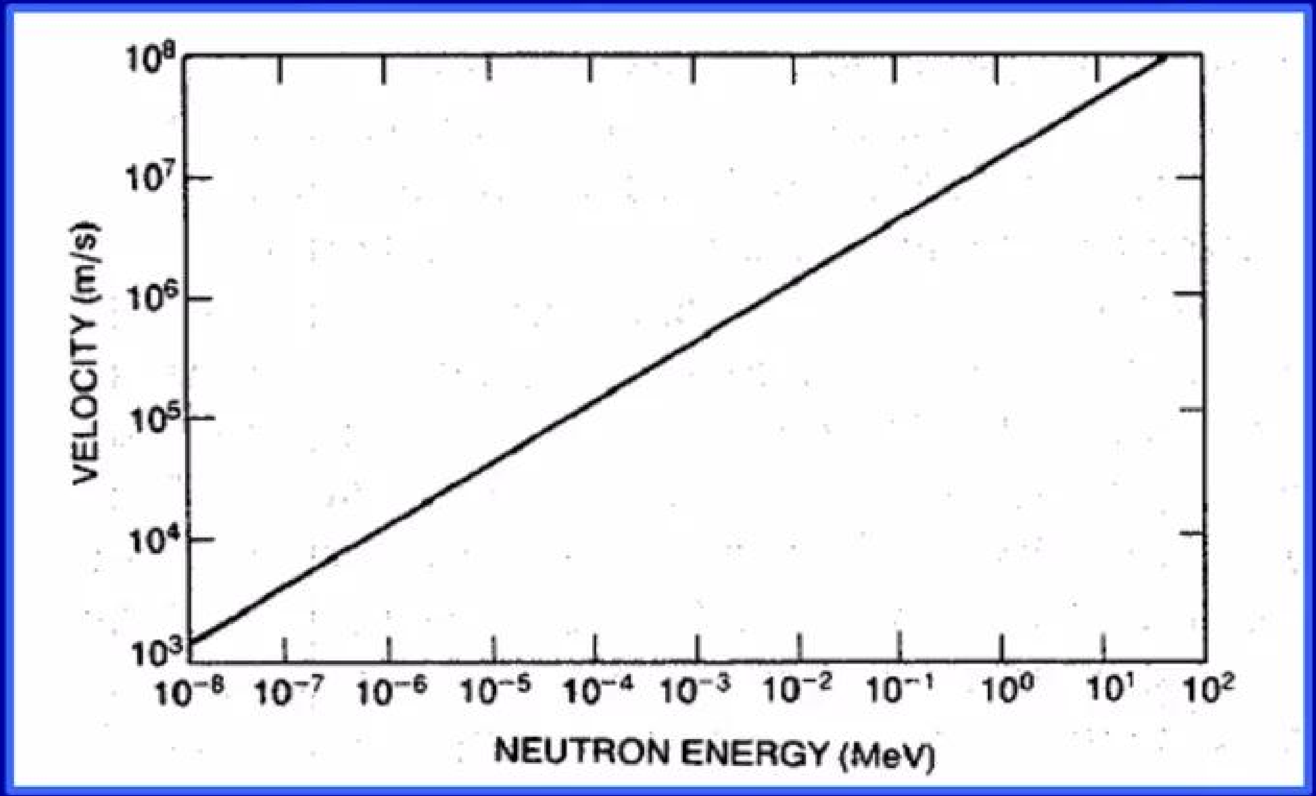
Collectively produced neutrons have ultra low momentum

Capture cross-sections on nuclei vastly higher than thermalized neutrons

Detectable fluxes of free neutrons rare in LENR experiments; virtually all captured

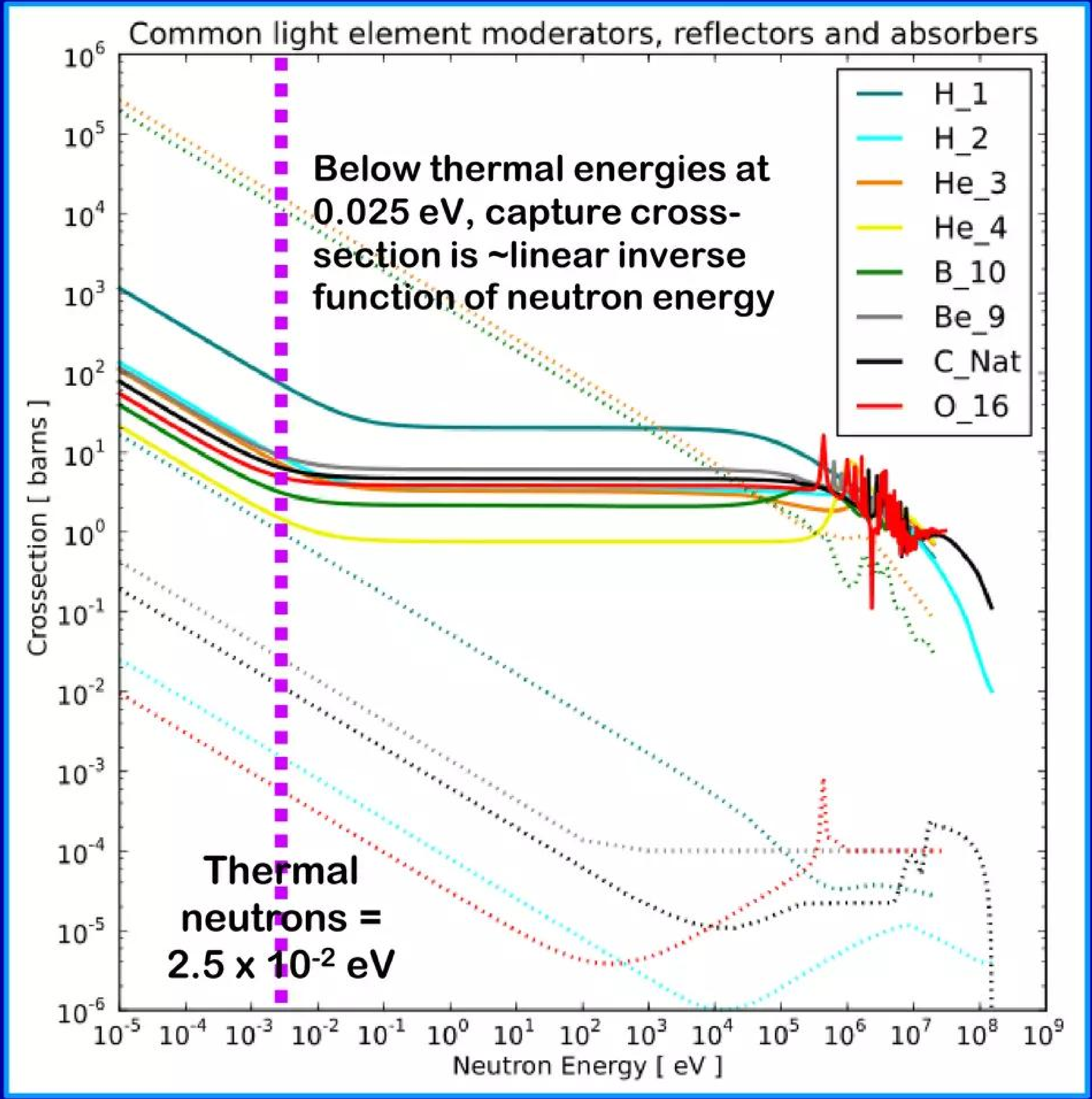
- ✓ If capture cross-sections of ULM neutrons could be measured, they would be far, far beyond the left-side margins of graph over to right
- ✓ Capture of ULM neutrons is very fast process: occurs in just picoseconds
- ✓ All isotopes shown in right chart would have much larger capture cross-sections for ULM neutrons

Velocity (m/sec) vs. Neutron energy



Source: P. Rinard

Neutron capture cross-sections vs. neutron energy



Below thermal energies at 0.025 eV, capture cross-section is ~linear inverse function of neutron energy

Thermal neutrons = 2.5×10^{-2} eV

Figure adapted from source: Wikipedia

Widom-Larsen explains lack of gamma radiation in LENRs

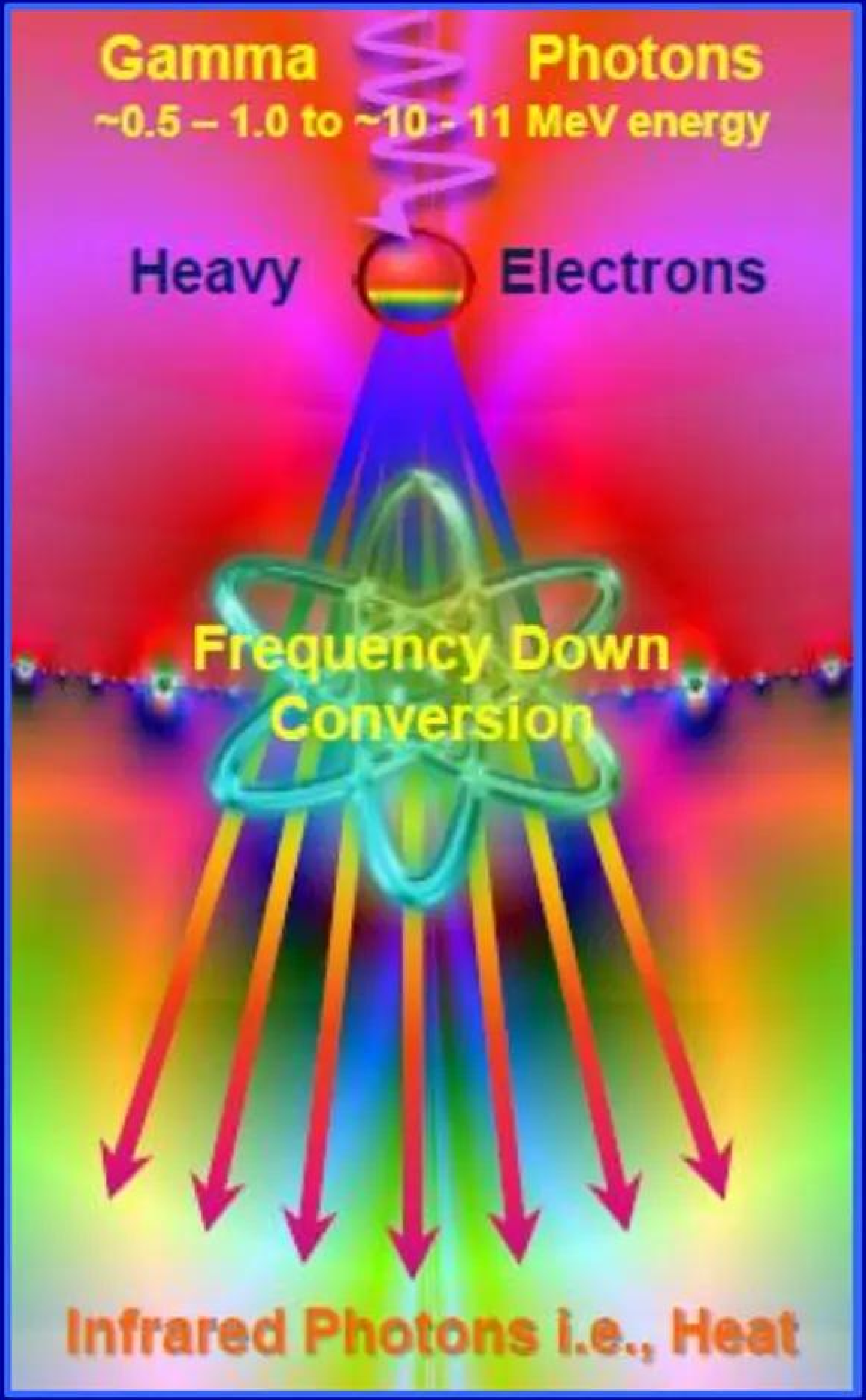
Unreacted heavy-mass electrons directly convert gammas to IR (heat)

Process occurs at high efficiency in condensed matter, not in magnetic plasmas

Issued Lattice patent: US 7,893,414 B2

Inventors: Lewis Larsen and Allan Widom

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



Clean copy of patent as-issued is available at:

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

Widom-Larsen explains lack of gamma radiation in LENRs

Many-body collective Q-M effects and heavy-mass electrons enable this

Net result is that hard gamma radiation not emitted by LENRs; need no shielding

- ✓ All of the many-body charged particles found within condensed matter 2 nm to 100+ micron 3-D LENR-active surface patches (in which there is also breakdown of the Born-Oppenheimer approximation) --- surface plasmon or π electrons; protons or deuterons; produced ULM neutrons --- oscillate collectively and (key point) are mutually quantum mechanically(Q-M) entangled with each other. This unique characteristic of LENR-active surface sites is explained in detail in several Lattice SlideShare presentations. Existence of such local Q-M entanglement is well-supported by recently published, outstanding work by other researchers who conduct research totally outside the field of LENRs
- ✓ Because of the above, when ULM neutrons are created collectively, their 3-D DeBroglie wave functions must perforce span all three spatial dimensions of particular LENR-active patches in which they are created. During brief interval of several picoseconds before such neutrons are locally captured by atoms located with the (we think) oblate spheroidal spatial boundaries of ULM neutrons' extended DeBroglie wave functions within many-body patches, they are interacting with many different atoms that compete to capture neutrons. Thus, process has many-body scattering cross-section, NOT 2-body
- ✓ Note that only modest percentages of the total number of mass-renormalized electrons located within 3-D spatial Q-M domains of LENR-active patches will have absorbed enough energy from very high (> 2 x 10^{11} V/m) local electric fields to cross the 0.78 MeV threshold for making ULM neutrons by the direct e + p electroweak reaction. Therefore, vast majority of these heavier-than-normal electrons are locally present but unreacted

LENRs could be much better than fission or fusion energy

Gammas from ~0.5 - 1.0 MeV up thru 10 - 11 MeV converted into infrared

- ✓ When ULM neutrons capture onto atoms located inside entangled 3-D Q-M domains of LENR-active patches, there is commonly prompt gamma photon emission by such atoms. Please recall that the DeBroglie wave functions of entangled, mass-renormalized heavy-mass electrons are 3-D, not 2-D domains. Since neutron capture gamma photon emission occurs inside the 3-D quantum mechanical structures of 3-D LENR-active patches, there are always excess heavy electrons available nearby to absorb any gamma emissions and convert them directly into infrared (IR) photons. Thus, it doesn't matter where gamma emissions occur inside a given 3-D patch, they will always get converted to IR, which is exactly what has been observed experimentally. Large fluxes of hard gammas will not be emitted from such patches, no matter from whatever x-y-z direction they are measured

- ✓ Above conversion also applies to any gammas that might be produced in conjunction with beta-decays of unstable, very neutron-rich isotopes that are briefly present in LENR-active patches before they die. Overwhelming majority of very short-lived intermediate nuclear isotopes will have disappeared in serial cascades of beta-decay chains into stable end-product isotopes/elements before dynamic local populations of heavy-mass electrons disappear. This is consistent with experimental observations: using mass spectroscopy, post-experiment analyses can detect the presence of stable transmutation products in which prompt capture gammas were undoubtedly produced along the likely nucleosynthetic pathway; however, MeV-energy gamma fluxes cannot be measured during LENR transmutation processes. Ergo, gammas were converted to something else, namely IR photons that are manifested calorimetrically as excess heat

Miley et al. 1996 experiments reported LENR transmutations

Ni cathodes were analyzed post-experiment to detect nuclear products

"Nuclear transmutations in thin-film Nickel coatings undergoing electrolysis"

http://newenergytimes.com/v2/library/1996/1996MileyG-NuclearTransmutations-JNE-RAW.pdf

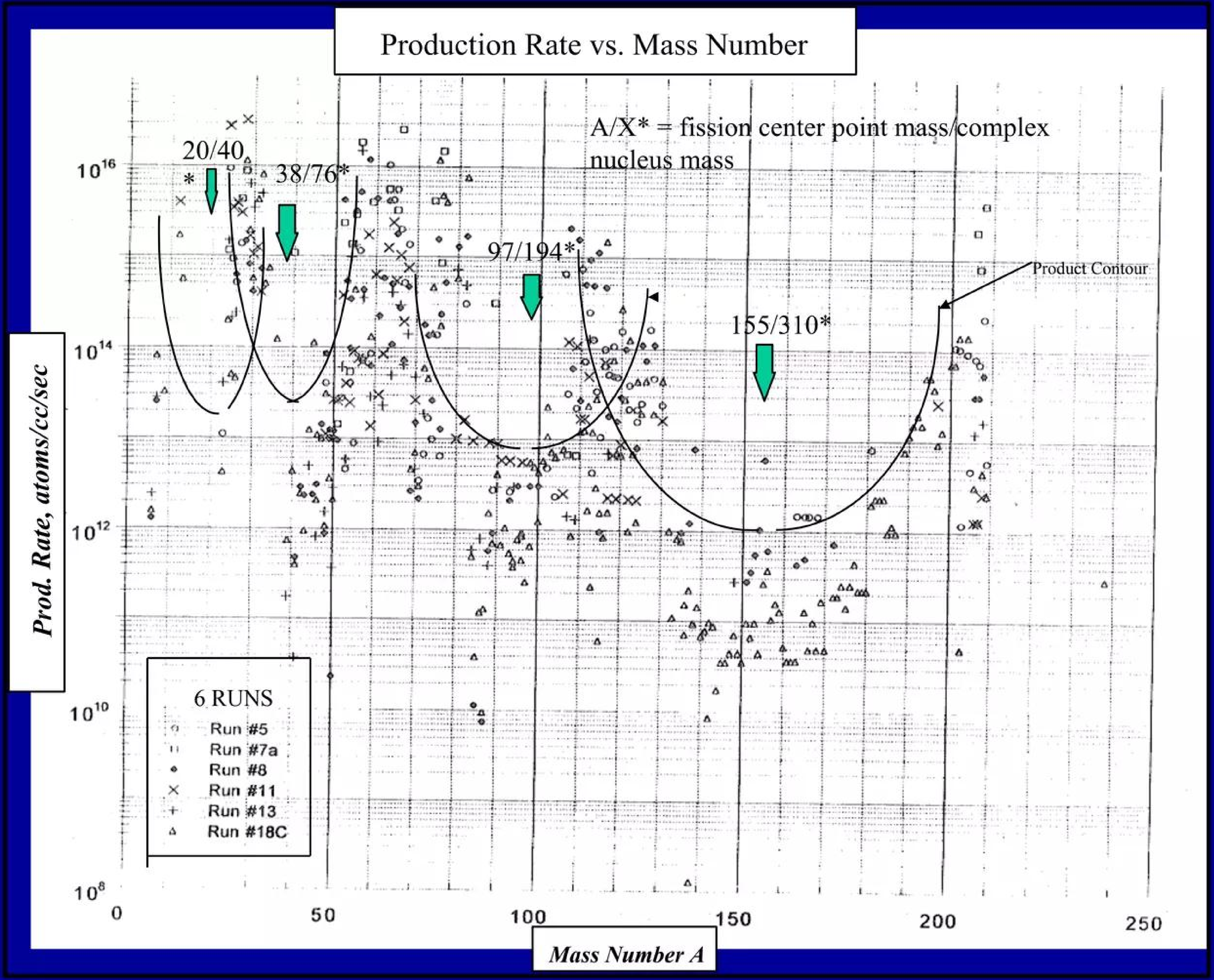
Abstract:

"Experiments using 1-mm plastic and glass microspheres coated with single and multilayers of thin films of various metals such as palladium and nickel, used in a packed-bed electrolytic cell (Patterson Power Cell ™ configuration), have apparently produced a variety of nuclear reaction products. The analysis of a run with 650-Å film of Ni is presented here. Following a two-week electrolytic run, the Ni film was found to contain Fe, Ag, Cu, Mg, and Cr, in concentrations exceeding 2 atom % each, plus a number of additional trace elements. These elements were at the most, only present in the initial film and the electrolyte plus other accessible cell components in much smaller amounts. That fact, combined with other data, such as deviations from natural isotope abundances, seemingly eliminates the alternate explanation of impurities concentrating in the film … 1-molar lithium sulfate solution in light water was employed for the electrolyte. A small excess heat of approximately 0.5 ± 0.4 watts was recorded throughout the run. Reaction products were analyzed using a combination of secondary ion mass spectrometry (SIMS), Auger electron spectrometry (AES), energy dispersive x-ray (EDX) analysis, and neutron activation analysis (NAA) … Results showing a broad array of products such as found here have also been obtained with thin film coatings of other materials, e.g., Pd and multi-layers of Pd and Ni. The yields of the major elements contributing depend on the film material, however … The array of products found in these experiments is consistent with recent studies of solid Pd and Au electrodes by Mizuno et al. [19] and Ohmori and Enyo [22], respectively. A distinct advantage of thin electrode construction used here … is that the reaction zone becomes well defined, enabling quantitative measurements of the amounts of various products."

Plot of the data shows production rate vs. mass number A

In 1997 Miley et al. published their compilation of data reported in 1996

Graph exhibits pronounced 5-peak product mass spectrum; also seen by Mizuno



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)

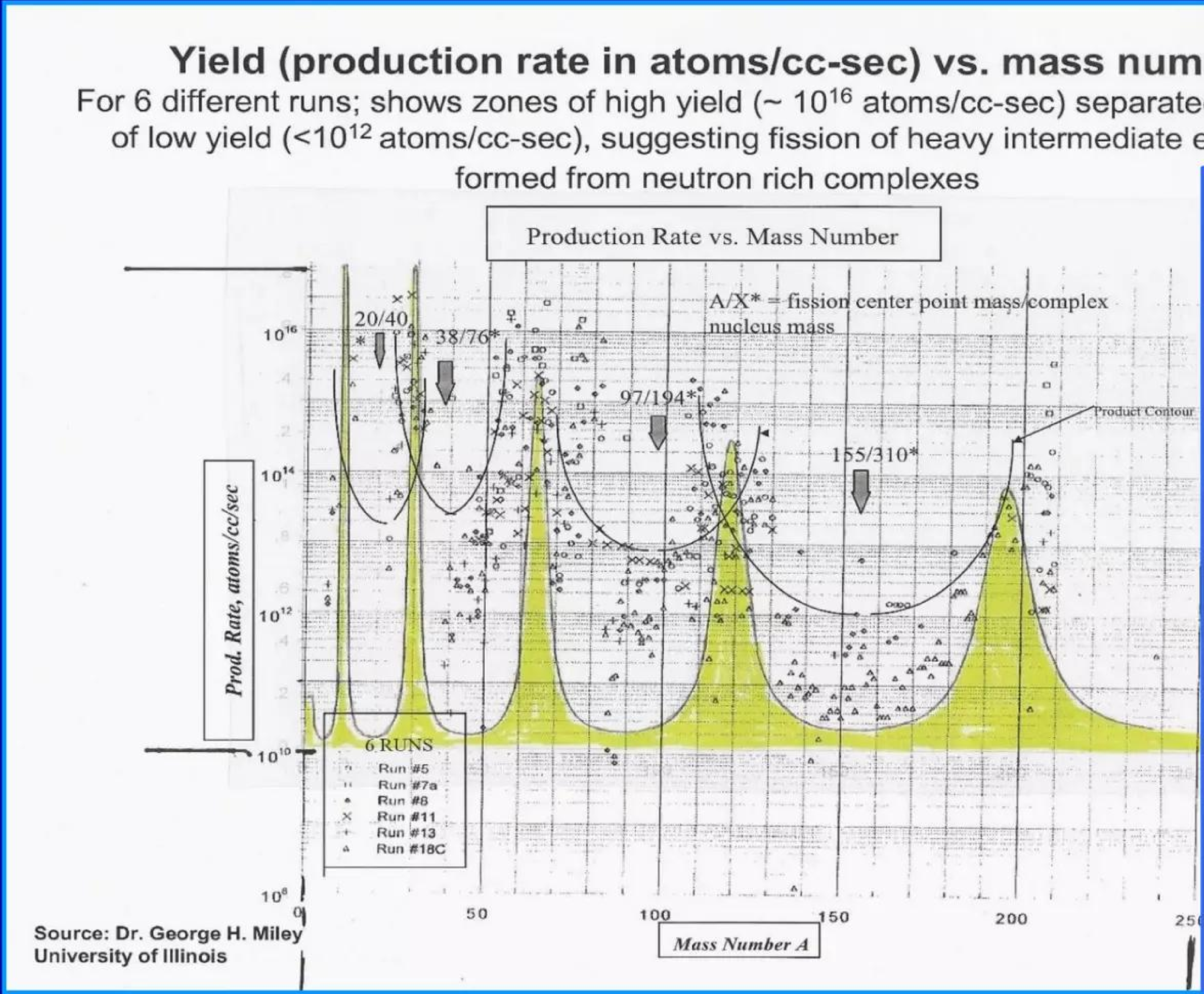
Miley et al. LENR experiments show 5-peak mass spectrum

Is unique signature of ultralow energy neutron capture and beta$^-$ decays

Widom & Larsen predict 5-peak mass spectrum with a simple 2-parameter model

Product mass-spectrum predicted by W-L model vs. Miley et al.'s raw rate data

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



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

Model only generates a 5-peak resonant capture spectrum at zero momentum limit ; higher energy neutrons won't produce the same distribution of neutron-driven nuclear transmutation products

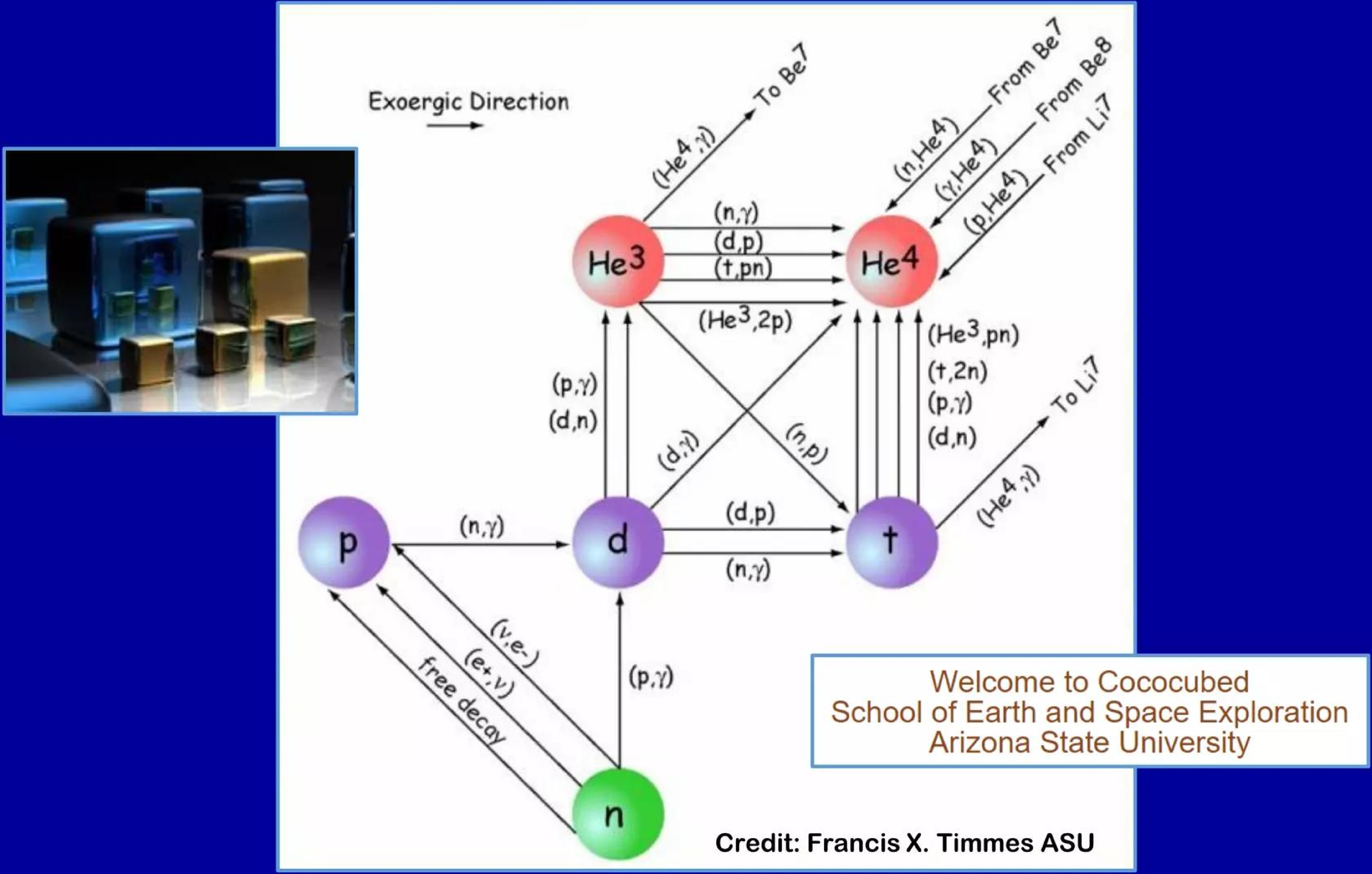
Chart presents Miley's raw data; yellow peaks and valleys show raw results of W-L neutron optical potential model superimposed directly onto Miley's data

http://arxiv.org/pdf/cond-mat/0602472v1.pdf

Big Bang nucleosynthetic reactions out through Helium

Note that D, T, He-4 are also produced via neutron capture + γ emission

Theorists believe reactions below occurred within 250 seconds of Big Bang event



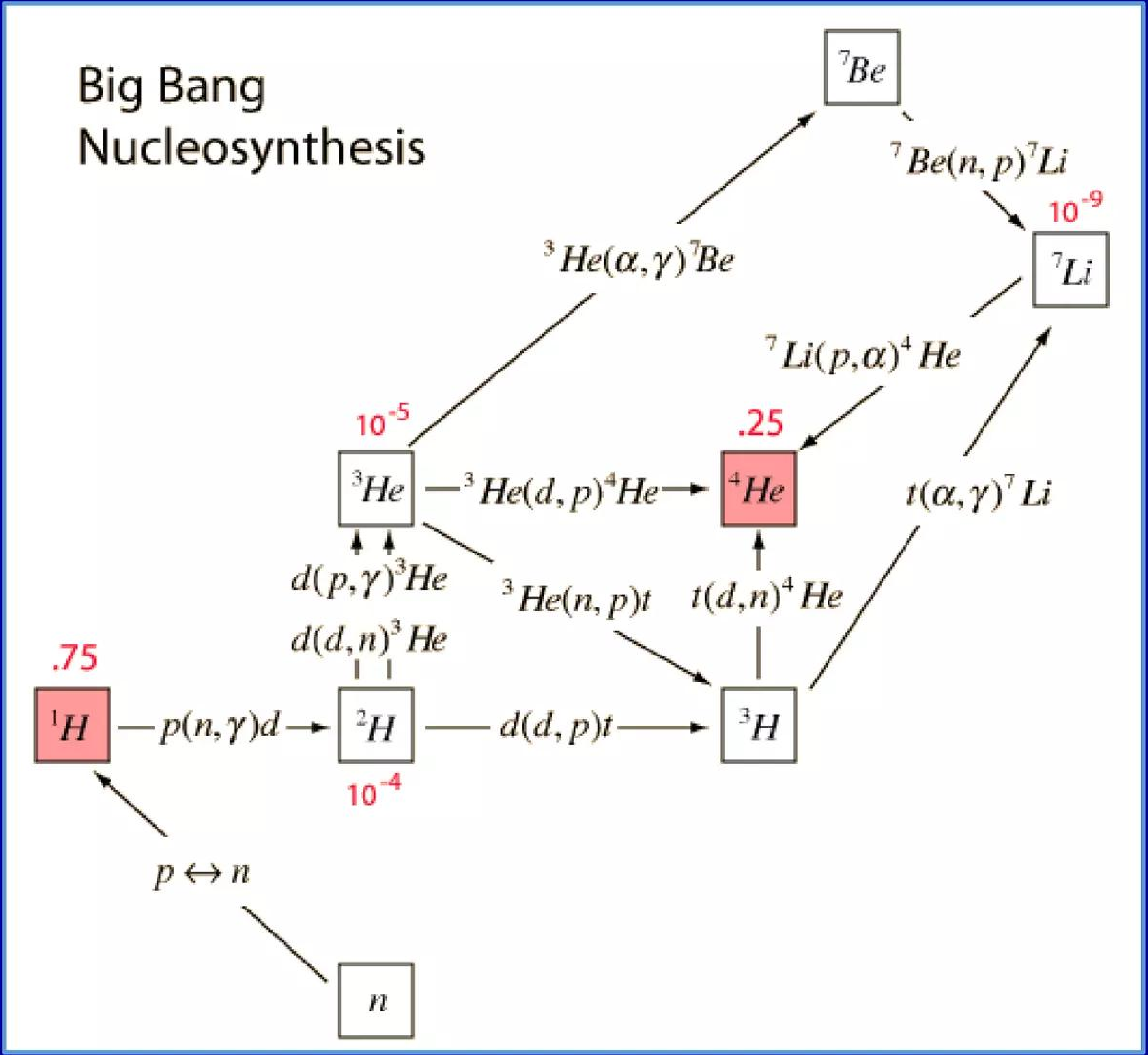
Welcome to Cococubed
School of Earth and Space Exploration
Arizona State University

Credit: Francis X. Timmes ASU

Big Bang nucleosynthetic reactions out through Beryllium

Deuterium, Helium, Lithium, Beryllium all considered primordial elements

Theorists believe that Li and Be were created within ~300,000 years after Big Bang



LENR cycle begins with ULM neutron capture on Lithium

Lithium cycle effectively observed in experiments with electrolytic cells

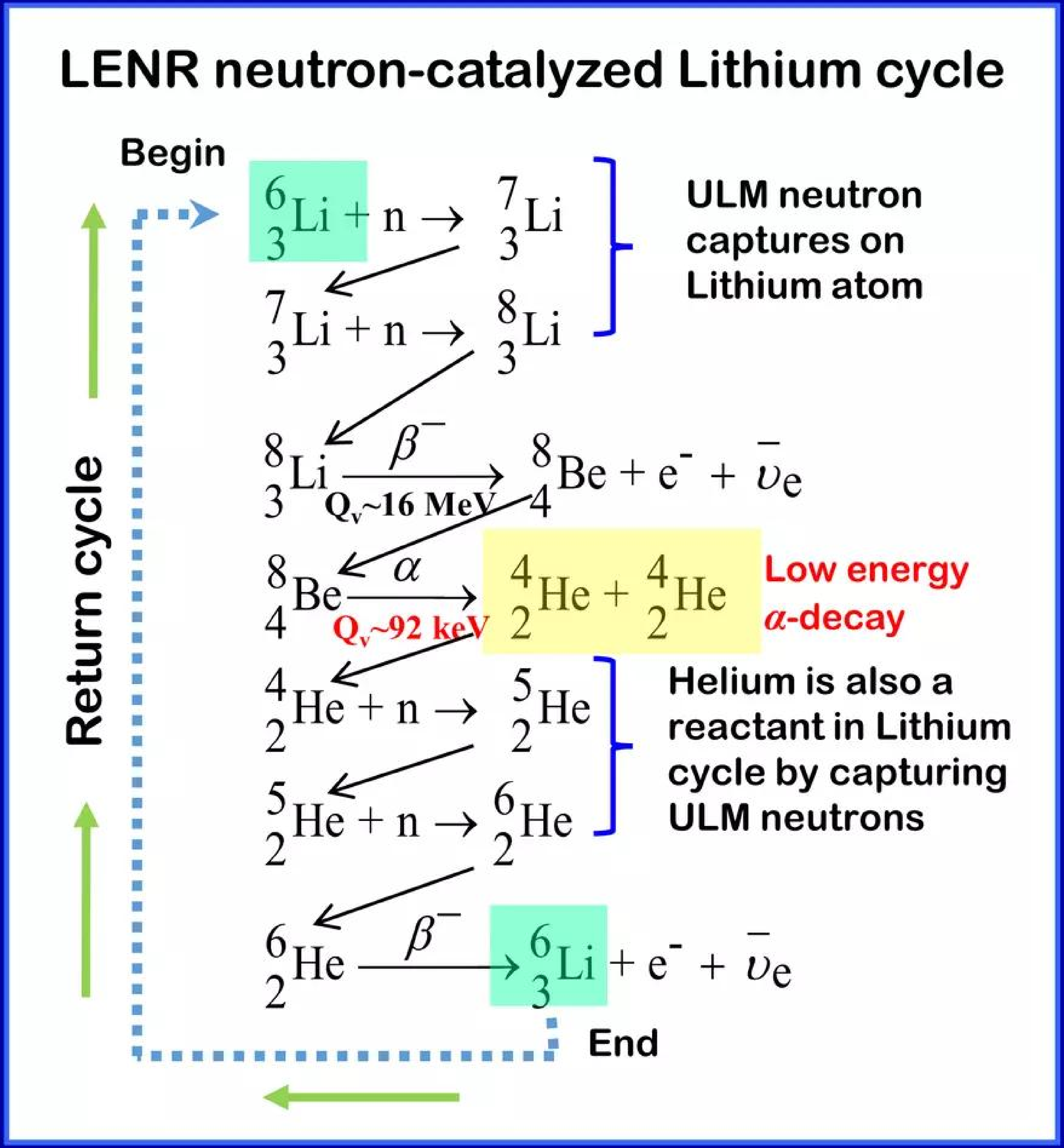
Series of hard-radiation-free LENR reactions release more heat than D-D fusion

Production of primordial elements was observed in LENR experiments:

$$Q\{\,^6_3\mathrm{Li} + 2n \rightarrow 2\,^4_2\mathrm{He} + \mathrm{e}^- + \bar{\nu}_\mathrm{e}\} \approx 26.9\,\mathrm{MeV}$$

- ✓ Nucleosynthetic cycle first disclosed by Widom & Larsen in 2006 *EPJC* paper
- ✓ Series of LENR reactions beginning with neutron capture on Lithium-6 has large + binding energy Q_v of ~ 26.9 MeV
- ✓ Cycle creates primordial He and Be; is 'leaky' via ULM neutron capture on Li-8; this produces unstable Li-9 (178 msec) which β^- decays into stable Be-9 (100%)
- ✓ LENR Lithium cycle could be useful in commercial power generation systems; no deadly MeV radiation produced and no very long-lived radioactive wastes

Nucleosynthesis in condensed matter



LENR neutron-catalyzed Lithium cycle

Begin

$^6_3\mathrm{Li} + \mathrm{n} \rightarrow \,^7_3\mathrm{Li}$

$^7_3\mathrm{Li} + \mathrm{n} \rightarrow \,^8_3\mathrm{Li}$

ULM neutron captures on Lithium atom

$^8_3\mathrm{Li} \xrightarrow[Q_v\sim16\ \mathrm{MeV}]{\beta^-} \,^8_4\mathrm{Be} + \mathrm{e}^- + \bar{\upsilon}_\mathrm{e}$

$^8_4\mathrm{Be} \xrightarrow[Q_v\sim92\ \mathrm{keV}]{\alpha} \,^4_2\mathrm{He} + \,^4_2\mathrm{He}$

Low energy α-decay

$^4_2\mathrm{He} + \mathrm{n} \rightarrow \,^5_2\mathrm{He}$

$^5_2\mathrm{He} + \mathrm{n} \rightarrow \,^6_2\mathrm{He}$

Helium is also a reactant in Lithium cycle by capturing ULM neutrons

$^6_2\mathrm{He} \xrightarrow{\beta^-} \,^6_3\mathrm{Li} + \mathrm{e}^- + \bar{\upsilon}_\mathrm{e}$

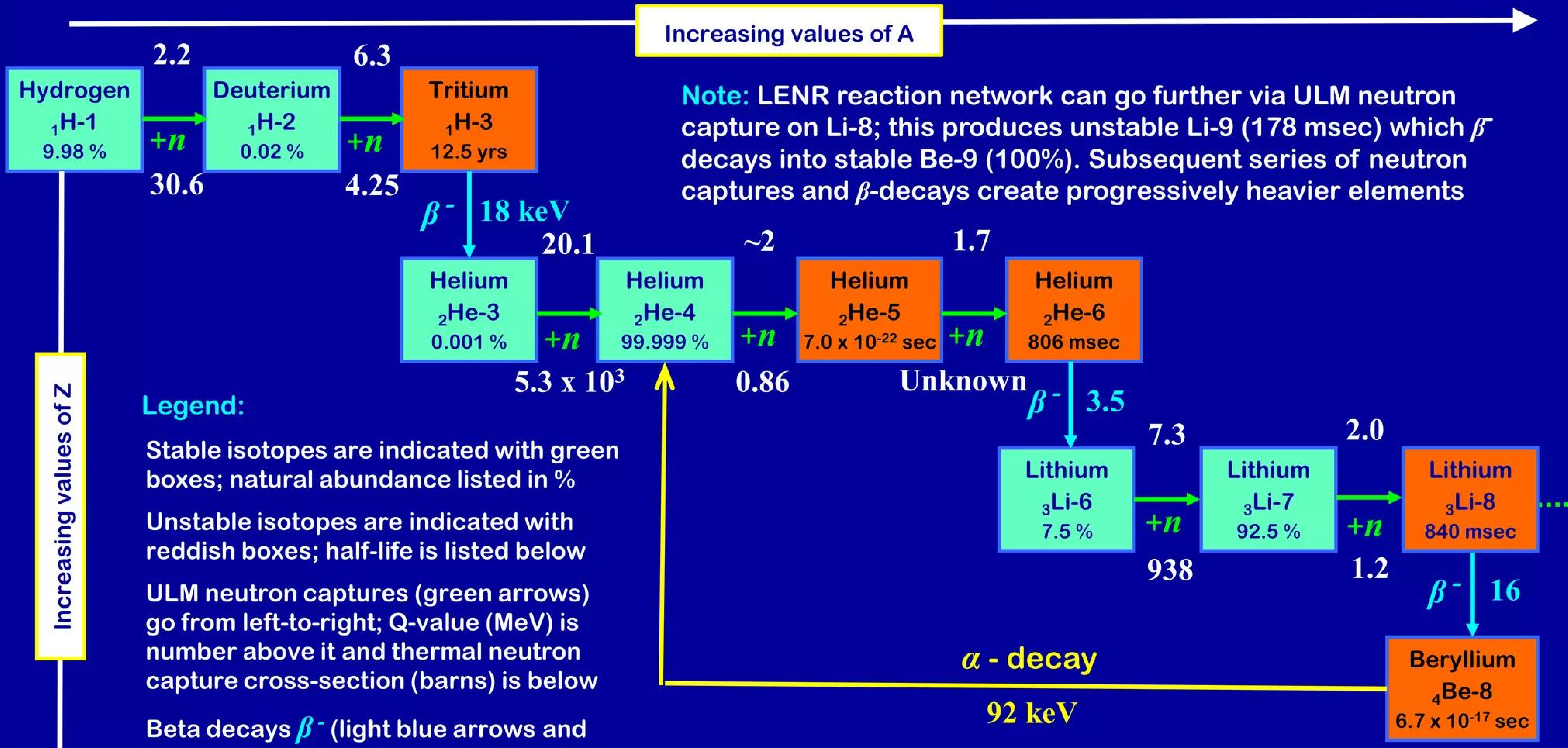
End

Return cycle

LENR nucleosynthetic reactions occur in condensed matter

Combination of neutron captures and β^- decays produce D, He, Li and Be

Big Bang elements produced in tabletop experiments under moderate conditions



Increasing values of A

Increasing values of Z

Hydrogen ${}_{1}\text{H-1}$ 9.98 %

2.2 +*n* 30.6

Deuterium ${}_{1}\text{H-2}$ 0.02 %

6.3 +*n* 4.25

Tritium ${}_{1}\text{H-3}$ 12.5 yrs

β^- 18 keV

Helium ${}_{2}\text{He-3}$ 0.001 %

20.1 +*n* 5.3 x 10^3

Helium ${}_{2}\text{He-4}$ 99.999 %

~2 +*n* 0.86

Helium ${}_{2}\text{He-5}$ 7.0 x 10^{-22} sec

1.7 +*n* Unknown

Helium ${}_{2}\text{He-6}$ 806 msec

β^- 3.5

Lithium ${}_{3}\text{Li-6}$ 7.5 %

7.3 +*n* 938

Lithium ${}_{3}\text{Li-7}$ 92.5 %

2.0 +*n* 1.2

Lithium ${}_{3}\text{Li-8}$ 840 msec ....

β^- 16

Beryllium ${}_{4}\text{Be-8}$ 6.7 x 10^{-17} sec

α - decay

92 keV

Note: LENR reaction network can go further via ULM neutron capture on Li-8; this produces unstable Li-9 (178 msec) which β^- decays into stable Be-9 (100%). Subsequent series of neutron captures and β-decays create progressively heavier elements

Legend:

Stable isotopes are indicated with green boxes; natural abundance listed in %

Unstable isotopes are indicated with reddish boxes; half-life is listed below

ULM neutron captures (green arrows) go from left-to-right; Q-value (MeV) is number above it and thermal neutron capture cross-section (barns) is below

Beta decays β^- (light blue arrows and numbers) go top-to-bottom; isotope's decay energy (MeV unless otherwise noted) listed to right of the arrow

Alpha decay of Be-8 is in bright yellow

Gamma emissions are not shown on chart because they are automatically converted directly into benign infrared photons by heavy-mass SP electrons per the Widom-Larsen theory; see Lattice patent US # 7,893,414 B2

Production of Deuterium & Tritium from Hydrogen w. LENRs

Unaware of neutron capture on ^{1}H because 2.2 MeV gamma line is absent

Hard gamma emission doesn’t occur because of W-L direct conversion to infrared

“Laser-induced synthesis and decay of Tritium under exposure of solid targets in heavy water”
E. Barmina *et al.*, arXiv:1306.0830v1 June 3, 2013

Widom-Larsen theory posits electric currents and laser irradiation can be combined to provide input energy used to drive neutron production electroweak reactions. Theory is consistent with Barmina *et al.*’s reported experimental results: Type #2 experiments that added electrolysis to laser irradiation of bulk targets generally produced substantially higher levels of Tritium activity. This would be expected per W-L because greater the quantity of usable input energy to produce neutron fluxes, the larger will be resulting Tritium production from neutron captures on Deuterium present as reactant. See discussion of this in:

http://arxiv.org/ftp/arxiv/papers/1306/1306.0830.pdf

Deuterium is also produced in LENR experiments: “… total number of deuteron tracks equals to 1% of the registered proton tracks with energy ≥ 0.3 MeV in the experiments without any preliminary deuterium concentration in the metal target.” see Adamenko *et al.*:

http://newenergytimes.com/v2/library/2005/2005Adamenko-Track-Measurements.pdf

Helium-4 production reliably reported in LENR experiments

“Cold fusioneers” erroneously claimed D-D fusion process caused results

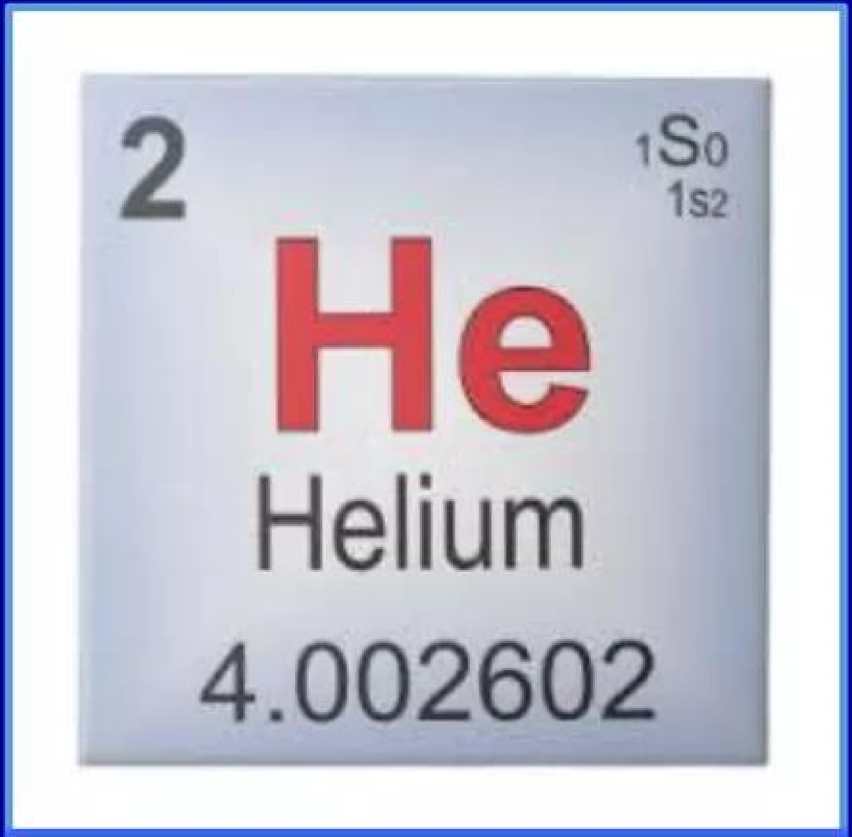
Unaware ULM neutrons were being produced & then captured by Li in electrolyte

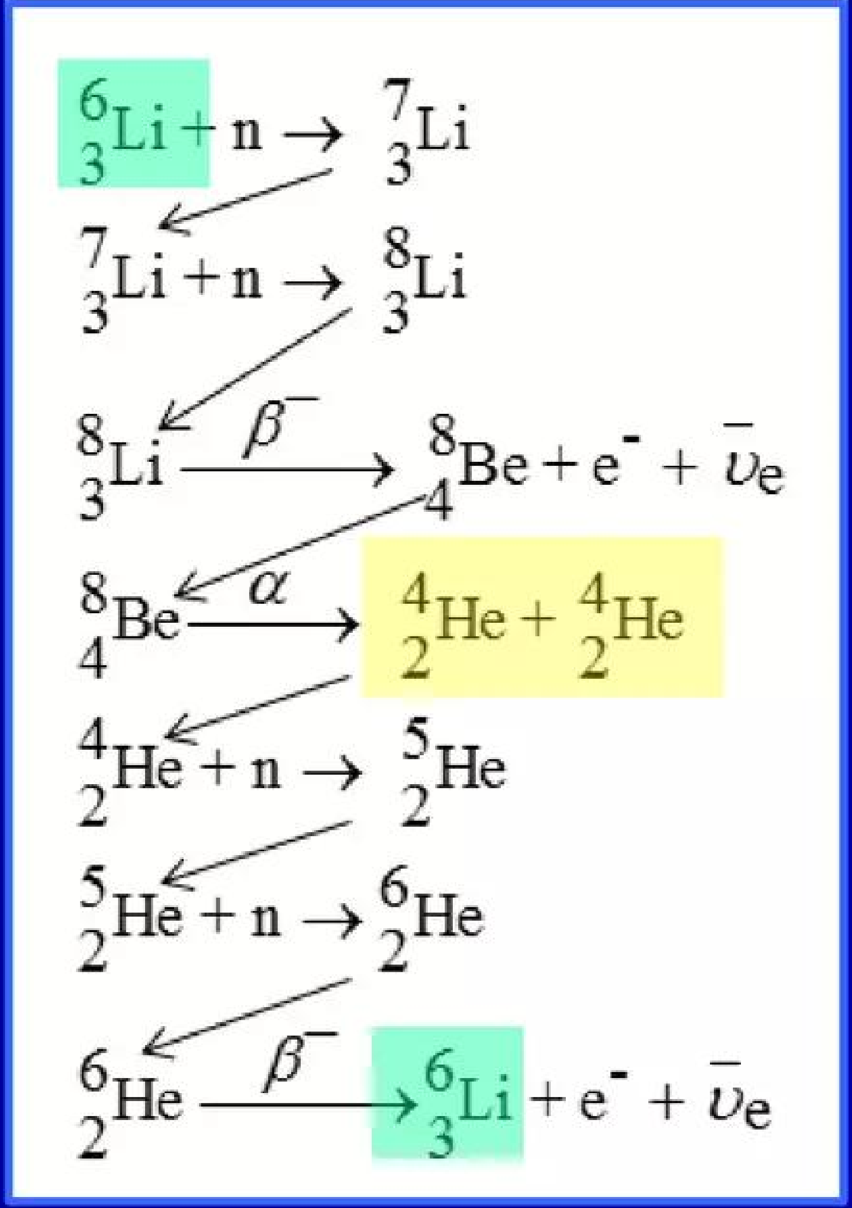
“Helium production during the electrolysis of D_2O in cold fusion experiments” B. Bush *et al.*, *Journal of Electroanalytical Chemistry* **304** pp. 271 - 278 (1991)

http://newenergytimes.com/v2/library/1991/1991BushBF-Miles-M-Helium-v0.pdf

Quoting from conclusions: “Experiments show a correlation between the generation of excess heat and power and the production of ^{4}He, established in the absence of outside contamination. This correlation in the Palladium/D_2O system provides strong evidence that nuclear processes are occurring in these electrolytic experiments. The major gaseous fusion product in D_2O + LiOD is ^{4}He rather than ^{3}He.”

These data and conclusions of Bush *et al.* are consistent with the capture of ULM neutrons per W-L theory and production of calorimetrically measured excess heat primarily via the Lithium-seed LENR reaction network shown to the right





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

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

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

$$^{8}_{4}\mathrm{Be} \xrightarrow{\alpha} {}^{4}_{2}\mathrm{He} + {}^{4}_{2}\mathrm{He}$$

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

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

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

ULM neutron capture on Lithium

Helium-4 production reliably reported in LENR experiments

“Cold fusioneers” erroneously claimed D-D fusion process caused results

Unaware ULM neutrons were being produced & then captured by Li in electrolyte

- ✓ D-D fusion reaction branches operate in parallel: #1 ~50% Q_v = ~4 MeV; #2 ~50% Q_v = ~2.3 MeV; #3 10^{-5} % Q_v = ~23 MeV
- ✓ At high rates, these D-D reactions will produce large fluxes of deadly MeV-energy neutron and hard gamma radiation
- ✓ Big problem for “cold fusion” hypothesis was that such hard radiation emissions were *never* observed, even when substantial amounts of excess heat were well-measured with accurate thermal calorimetry of electrochemical cells
- ✓ Cold fusioneers then assumed *ad hoc* that only branch #3 operates in such cells, but never provided any plausible physics to explain absence of penetrating gamma radiation
- ✓ According to Widom-Larsen theory, the perplexing lack of energetic neutrons and gammas is actually a key tip-off that W-L LENRs (rather than fusion processes) are really causing the long-controverial experimental anomalies. The second key tip-off that neutron-catalyzed transmutation is really occurring are reliable measurements of significant isotopic shifts in Lithium and Palladium post-experiment

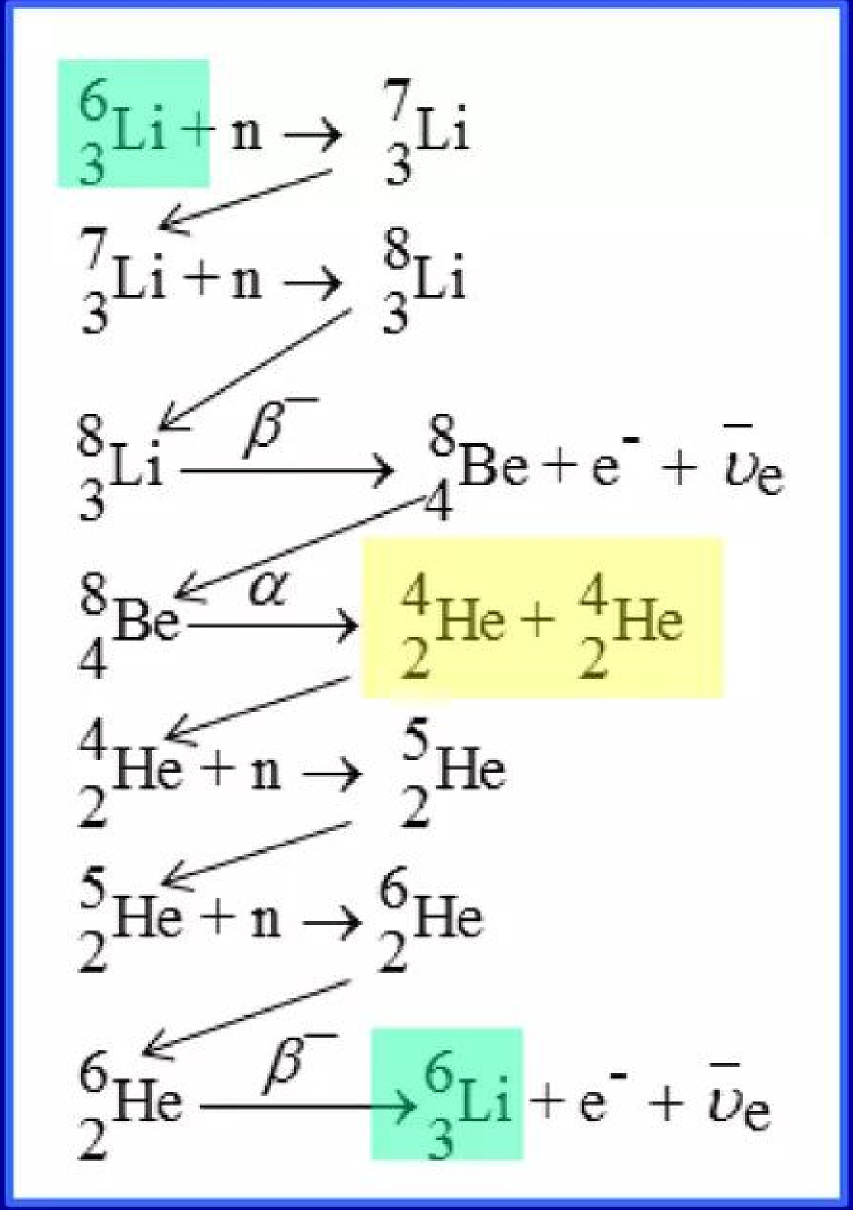
D-D fusion reaction has three branches

#1 $d + d \rightarrow t + p$

#2 $d + d \rightarrow {}^{3}_{2}He + n$

#3 $d + d \rightarrow {}^{4}_{2}He + \overset{radiation}{\gamma}$

LENR neutron capture on Lithium



ULM neutron capture on Lithium

Helium-4 is produced in D-T fusion reaction used by ITER

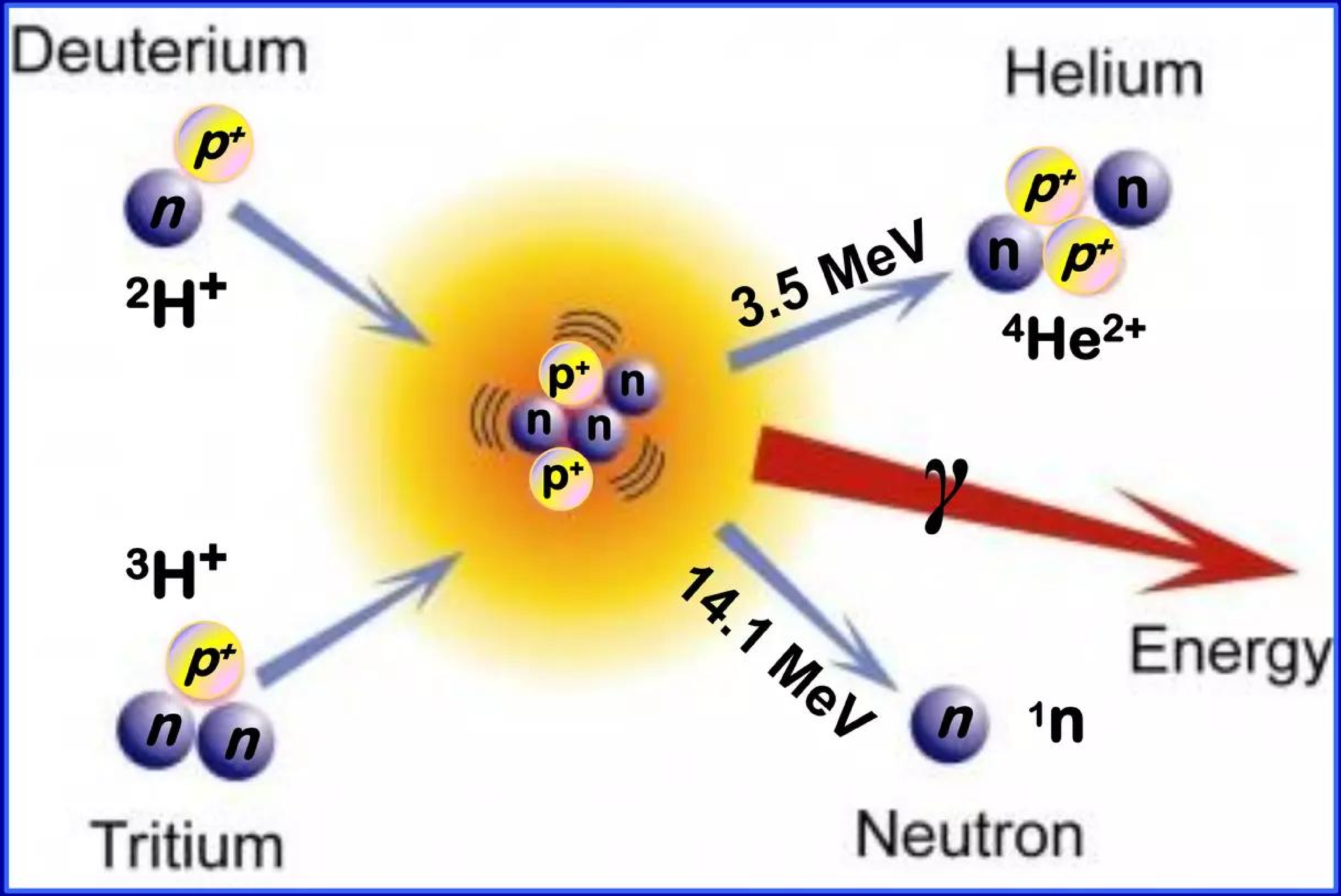
Triggering D-T fusion on Earth requires *huge* temperatures and reactors

D-T reaction creates dangerous 14.1 MeV neutrons and ~10^{-5} % ~16 MeV gammas

D-T fusion reaction

$$\underbrace{{}^{2}H^{+} + {}^{3}H^{+}}_{\text{fusion}} \rightarrow {}^{4}He^{2+} + {}^{1}n + 17.6\ \text{MeV}$$

ITER Tokamak reactor core temperature ~150 million ° C



D-T fusion reaction has three branches

#1 $d + t \rightarrow {}^{4}{}_{2}He$

#2 $d + t \rightarrow {}^{1}{}_{0}n$

#3 $d + t \rightarrow {}^{5}{}_{2}He + \gamma^{\,radiation}$

D-T fusion reaction's branches operate in parallel: #1 ~20% Q_v = ~3.5 MeV; #2 ~80% Q_v = ~14.1 MeV; #3 3.3 x 10^{-5} % Q_v = ~16.75 MeV *

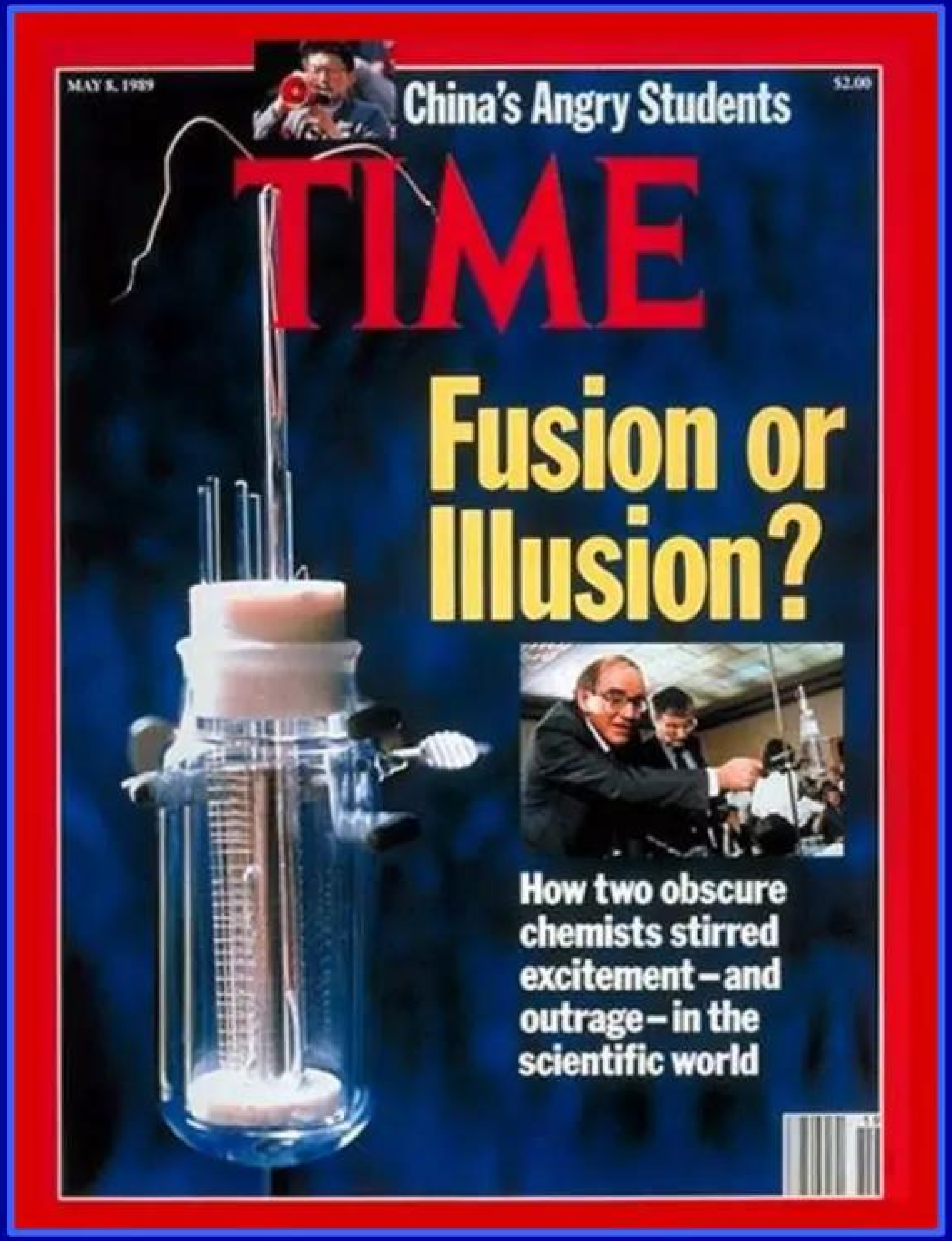
*** "D-T gamma-to-neutron branching ratio determined from inertial confinement fusion plasmas", Y. Kim *et al., Bull. Am. Phys. Soc.* 56 pp. 186 - 191 (2011)**

Early experimental results were inconsistent with fusion

Key issue along with irreproducibility doomed Pons & Fleischmann

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

- ✓ Theorized D+D fusion in electrochemical cells, as envisioned by Pons & Fleischmann, was really just fevered scientific speculation unsupported by data
- ✓ However, 27 years later we now know that while P&F's theorized room temperature "cold fusion" mechanism was totally erroneous, their excess heat measurements were likely to have been correct and they probably really did produce some Helium-4
- ✓ Thanks to the Widom-Larsen theory, we can now understand and explain all of the early anomalous experimental results as well as the baffling absence of deadly energetic neutron and gamma radiation
- ✓ In 1989 and later, a number of other scientists used mass spectroscopy to measure isotopic shifts as evidence of nuclear processes in electrochemical cells: saw it in post-experiment analysis of cathodes; this data was lost in controversy about "cold fusion"



Time Magazine May 8, 1989

U.S. government & others observed Lithium isotopic shifts

Causation mysterious; unaware ULM neutrons were capturing on Lithium

Lithium-6 is also produced directly from β^- decay of short-lived unstable Helium-6

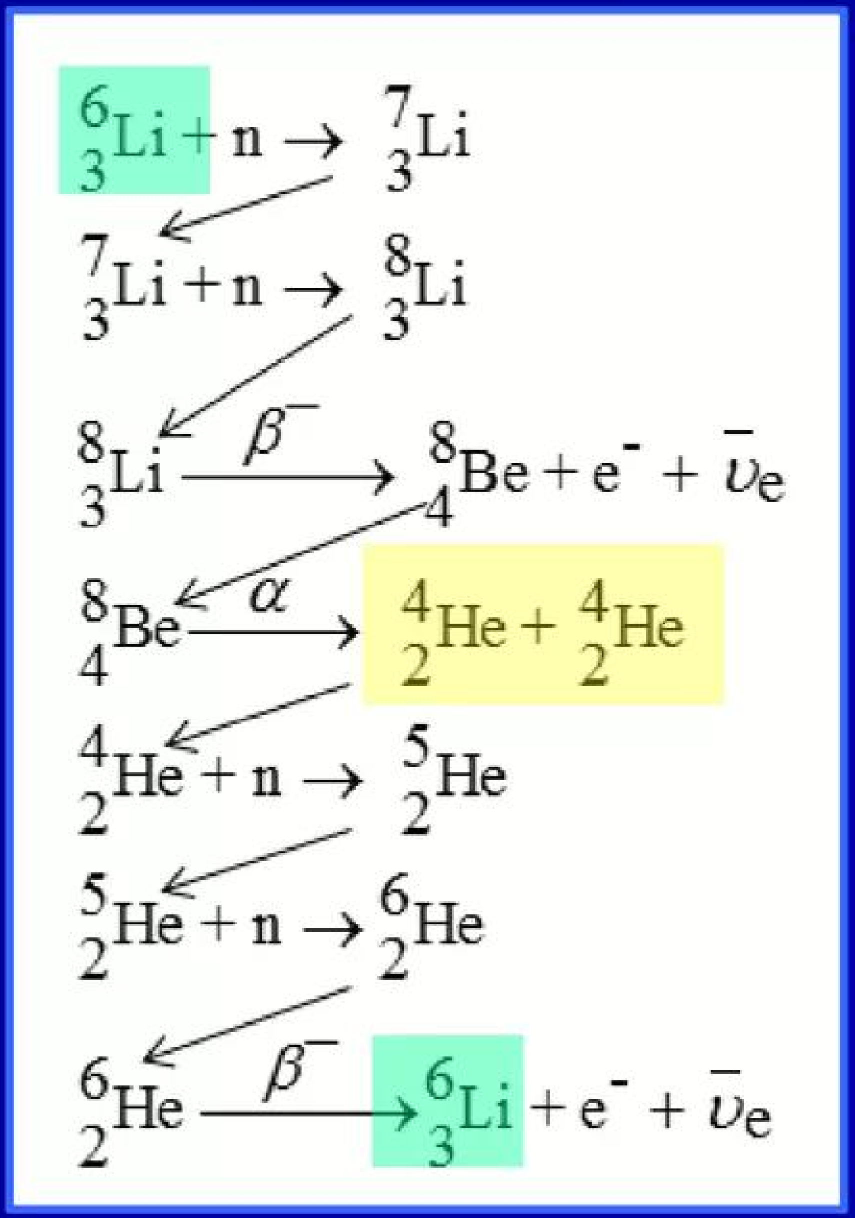
“Evidence for Lithium depletion in Pd exposed to gaseous Deuterium and Hydrogen” T. Passell, EPRI Conference: ICCF-9, Tsinghua U., Beijing, China 2002

http://newenergytimes.com/v2/library/2002/2002Passell-Li6-Depletion.pdf

Quoting from abstract: “Lithium showed Li-7/Li-6 ratios much higher than the 12.48 value for terrestrial Lithium.” This result is consistent with capture of ULM neutrons per W-L theory

- ✓ Mass spectroscopy analysis of Lithium isotopes collected from Pd cathode surfaces in electrolytic cell experiments with Lithium salts in electrolytes revealed large anomalous shifts in Li-7/Li-6 ratios; same result reported by several other researchers
- ✓ At an invitation-only EPRI/NSF workshop that was held in Washington, D.C. in October 1989, Dr. Edward Teller of Lawrence Livermore National Laboratory communicated report that LLNL scientists had observed anomalous depletion of Lithium-6 within first micron of Pd cathode surfaces in P&F-type electrolytic cells; see Slide #19 in:

  http://www.slideshare.net/lewisglarsen/lattice-energy-llc-us-government-labs-reported-clearcut-neutron-capture-data-from-pf-cells-in-oct-1989-may-13-2015



ULM neutron capture on Lithium

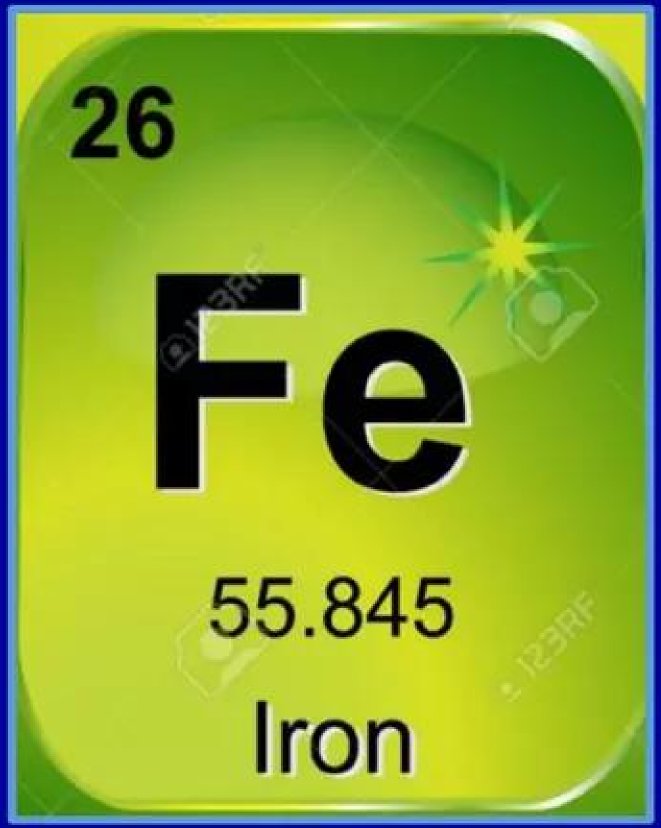
Texas A&M and BARC teams both reported C → Fe in 1994

Results published in peer-reviewed journal of American Nuclear Society

Authors gave incorrect explanation for results; unaware neutrons were causative

"Verification of the George Oshawa experiment for anomalous production of Iron from Carbon arc in water"
M. Singh *et al.*, *Fusion Technology* **26** pp. 266 - 270 (1994)

- ✓ ULM neutron production occurs near Carbon rod tips and on nanoparticles floating in water in regions of high currents and electric fields that form between the two ultrapure Carbon rods. Whenever a piece of debris leaves that region, neutron production stops quickly. Detritus lying on bottom of a reaction vessel is simply undergoing extremely short-lived radioactive β decays
- ✓ If the data of Sundaresan & Bockris and Singh *et al.* are correct, the only way that Iron can be produced from Carbon that quickly (becoming analytically detectable within an hour or two) is via LENR nucleosynthetic pathways that involve extremely neutron-rich isotopes
- ✓ For detailed technical discussion of all this see: http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewcarbon-seed-lenr-networkssept-3-2009



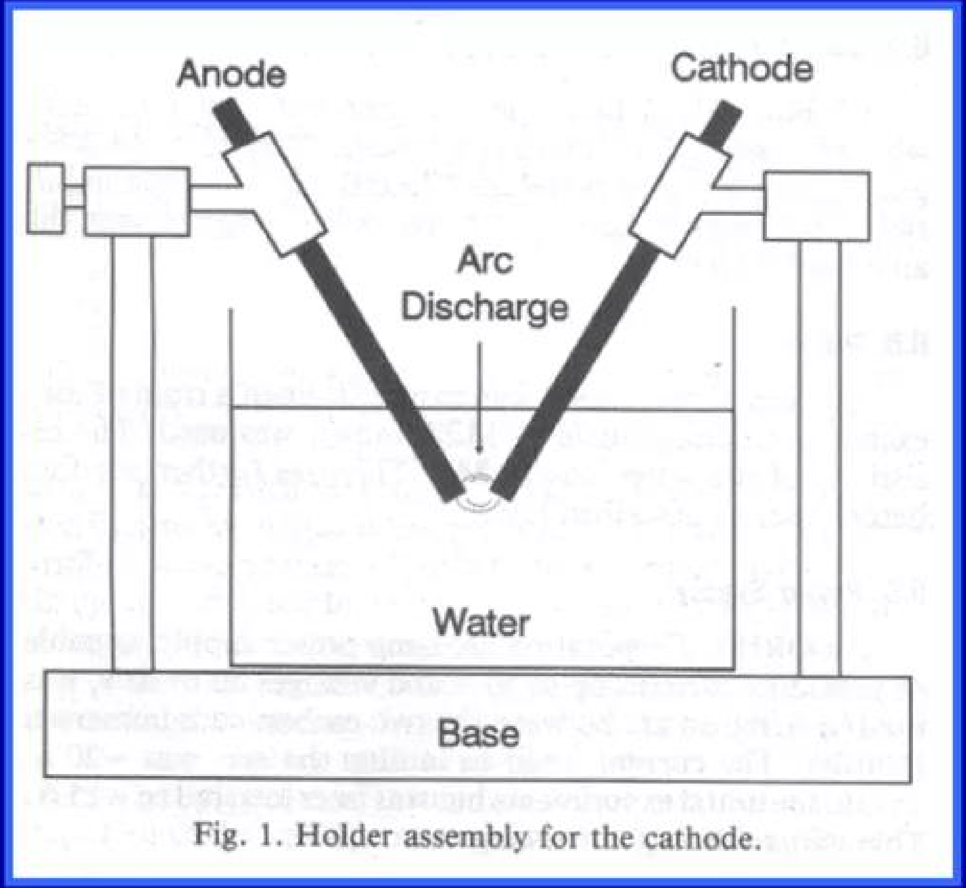


Fig. 1. Holder assembly for the cathode.

Texas A&M Experimental Apparatus
Source: 1994 *Fusion Technology* paper

Large Palladium isotopic shifts in LENR experiments

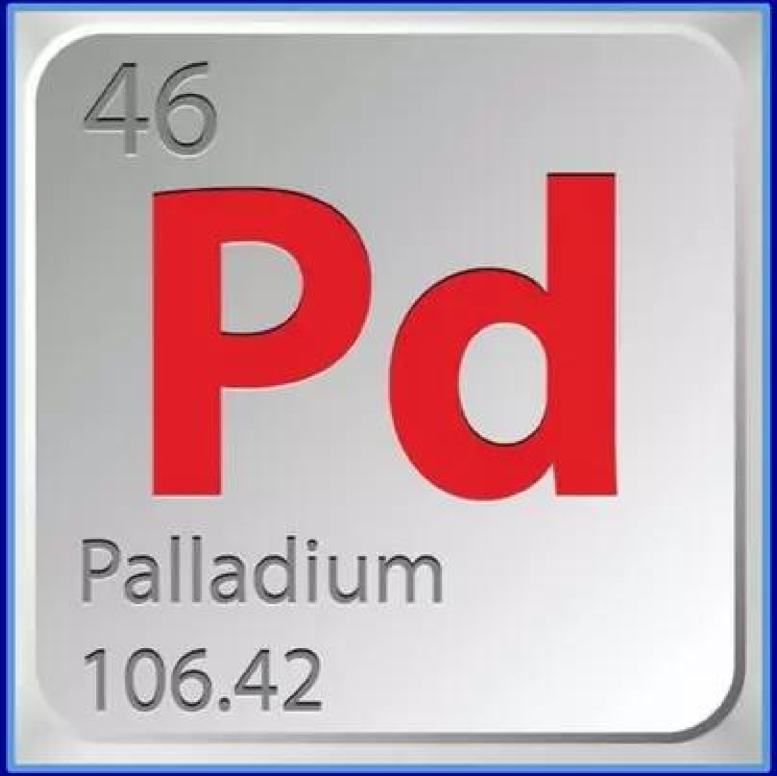
Number of LENR researchers published data on isotopic shifts in Pd

U.S. Navy reported anomalous Pd isotopic shifts at EPRI/NSF workshop in 1989


MASS/CHARGE ANOMALIES IN Pd AFTER
ELECTROCHEMICAL LOADING WITH DEUTERIUM

- Rolison & O'Grady of U.S. Naval Research Laboratory reported dramatic relative enrichment of Pd-106 and substantial parallel depletion of lighter Pd-105 isotope in same experiment
- Clearly observed the production of normally absent, unstable isotopes of Palladium (e.g., Pd-103, Pd-107, Pd-109, and Pd-111) during experiment PdD#4 (note post-experiment appearance of these additional Pd mass-peaks back in Fig. 1 shown earlier) but made no special note of this anomaly
- All this data is obviously well-explained by neutron captures on Palladium isotopes but Rolison *et al*. were reluctant to speculate because there was no clearly measurable evidence for the presence of substantial neutron fluxes during their experiments
- For detailed technical discussion of all this please see:

http://www.slideshare.net/lewisglarsen/lattice-energy-llc-us-government-labs-reported-clearcut-neutron-capture-data-from-pf-cells-in-oct-1989-may-13-2015



Mitsubishi Heavy Industries transmuted rare earth elements

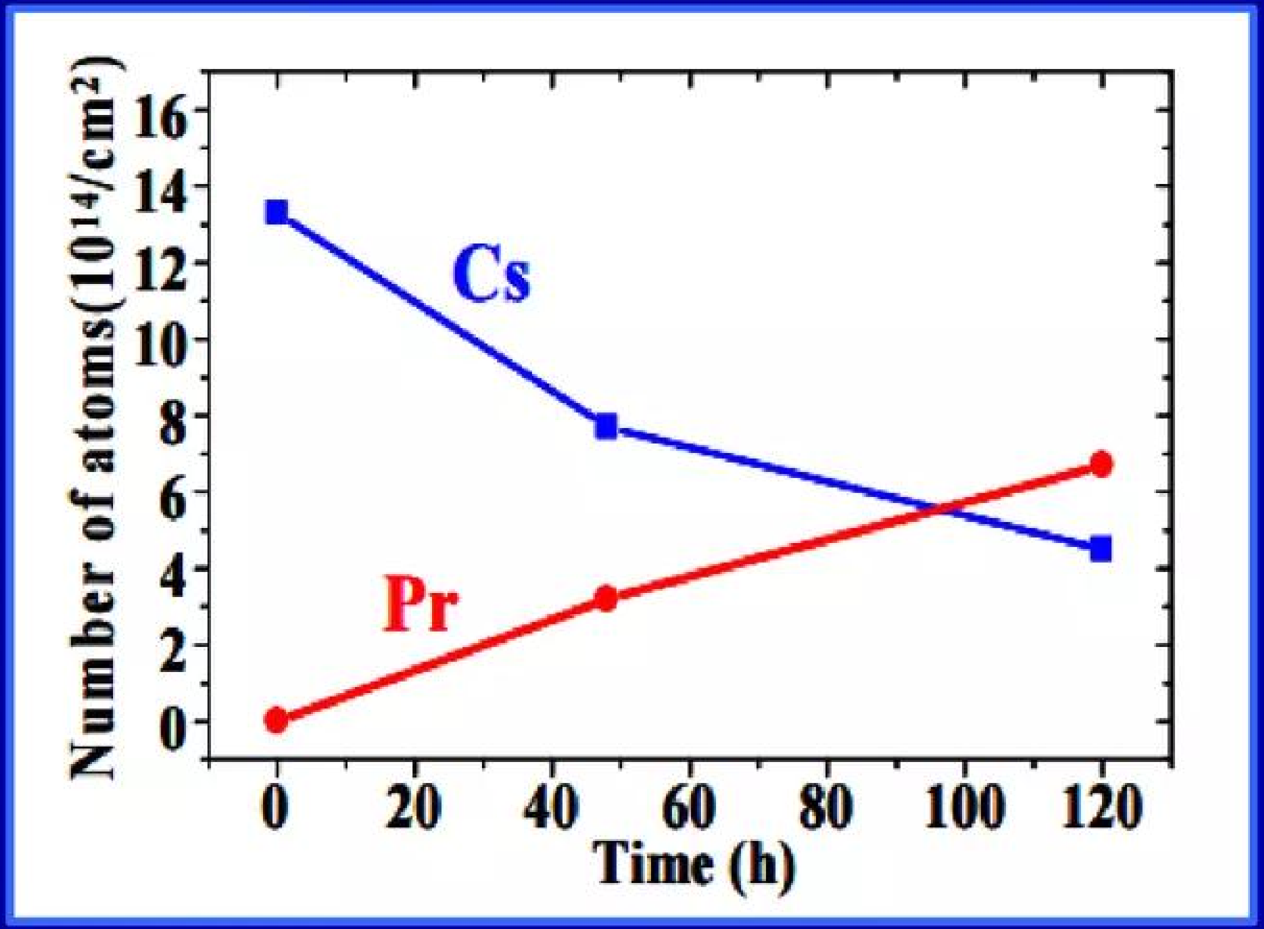
Experimental transmutation of Cesium into Praseodymium back in 2002

Results finally confirmed by Toyota and published in peer-reviewed *JJAP* in 2013

- ✓ **In October 2013, Toyota published a paper in the peer-reviewed *Japanese Journal of Applied Physics* which confirmed important experimental results that Mitsubishi Heavy Industries (MHI) had first published in the *JJAP* way back in 2002**
- ✓ **MHI had previously claimed transmutation of Cesium into Praseodymium via the forced diffusion of Deuterium gas through a thin-film heterostructure containing elemental Palladium using a permeation method pioneered by Mitsubishi; it is capable of triggering nuclear LENR reactions in condensed matter systems under very modest temperatures and pressures**
- ✓ **All of this experimental data is predicted and fully explained by the Widom-Larsen theory**
- ✓ **For technical discussion and details please see:**

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

Transmutation of Cesium into Praseodymium



Credit: Mitsubishi Heavy Industries (2002)

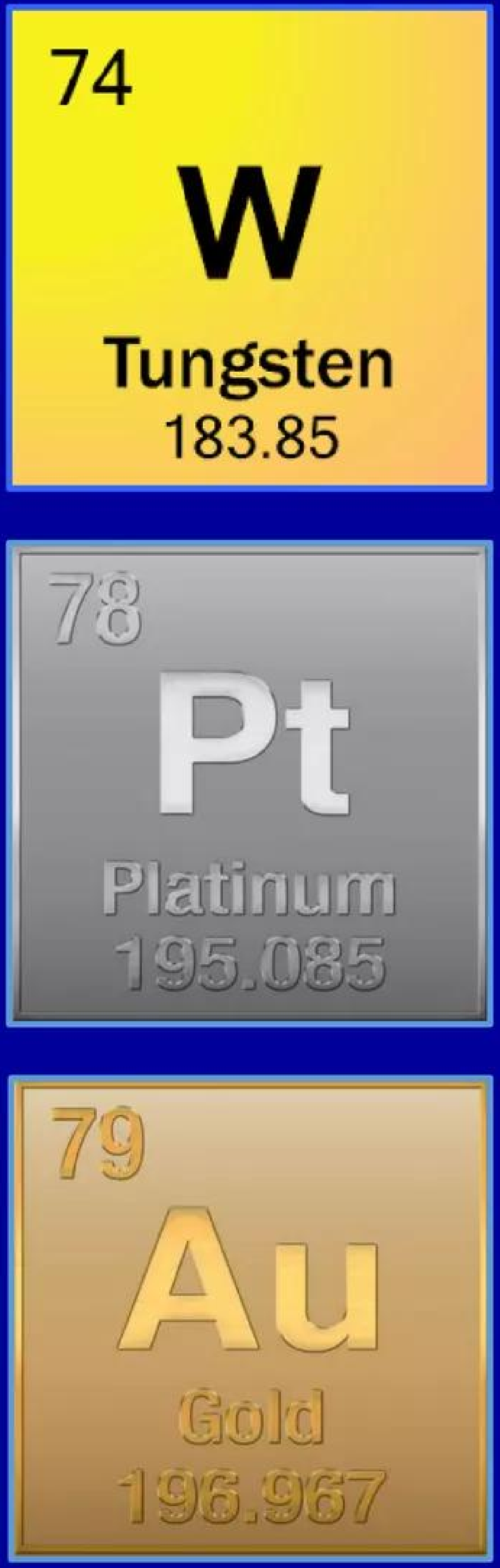
Mitsubishi Heavy Industries confirmed W → Pt → Au pathway

Results first published in *Nature* by Nagaoka in 1925; very few believed it

Mitsubishi first reported W → Pt results at 2012 American Nuclear Society meeting

W → Re → Os → Ir → Pt → Au

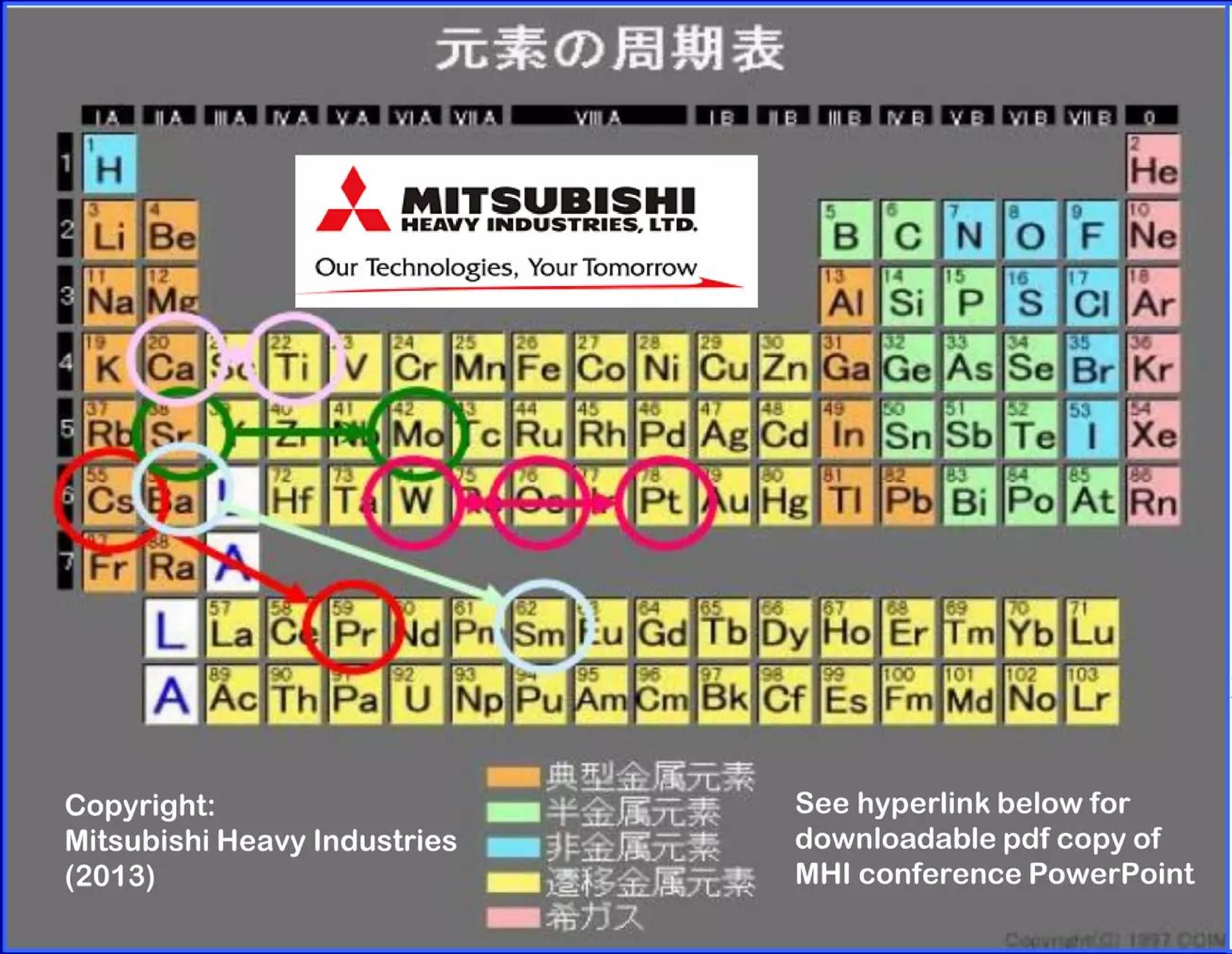
- ✓ In series of more than 200 successful experiments conducted in 1924-25, Prof. Hantaro Nagaoka produced detectable Gold and Platinum during high-current electric discharges between Thorium-free Tungsten (W) metal electrodes immersed in hydrocarbon transformer oil laced with elemental Mercury
- ✓ What Nagaoka did not know back in 1920s was that during powerful electric discharges ULM neutrons were being created from some surface plasmon electrons (present on Tungsten electrodes) that reacted directly with Hydrogen (protons) in transformer oil. Those neutrons were then captured by Tungsten atoms which ultimately transmuted them into Gold
- ✓ Despite publishing his results in *Nature*, Prof. Nagaoka was not generally believed. Using its Deuterium LENR permeation method, in 2012 Mitsubishi reported production of Platinum from an implanted Tungsten target. Mitsubishi's method produces far smaller neutron fluxes than Nagaoka's, so MHI only reached Platinum, which was in fact observed; please see: http://www.slideshare.net/lewisglarsen/lattice-energy-llc-lenr-transmutation-networks-can-produce-golddec-7-2012



Mitsubishi Heavy Industries transmuted number of elements

Results were published in the JJAP and reported at several conferences

All MHI's data is explained by Widom-Larsen with neutron captures and β decays



Copyright:
Mitsubishi Heavy Industries
(2013)

See hyperlink below for downloadable pdf copy of MHI conference PowerPoint

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

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

$$^{138}_{56}Ba \rightarrow ^{150}_{62}Sm$$

$$^{137}_{56}Ba \rightarrow ^{149}_{62}Sm$$

$$^{44}_{20}Ca \rightarrow ^{48}_{22}Ti$$

$$^{184}_{74}W \rightarrow ^{188}_{76}Os$$

$$^{182}_{74}W \rightarrow ^{190}_{78}Pt$$

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

Nucleosynthesis via W-L-S electroweak neutron production

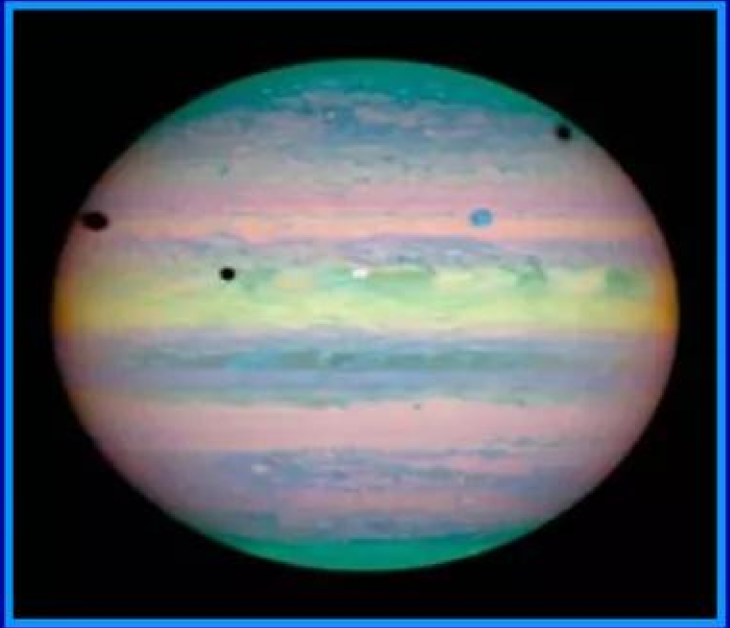
Not just on hot stars --- also in condensed matter at modest temperatures

Collective $e + p$ reactions can occur on stars, dust grains in nebulae, and planets

Planetary lightning produces neutrons

Earth: LENRs occur in many places

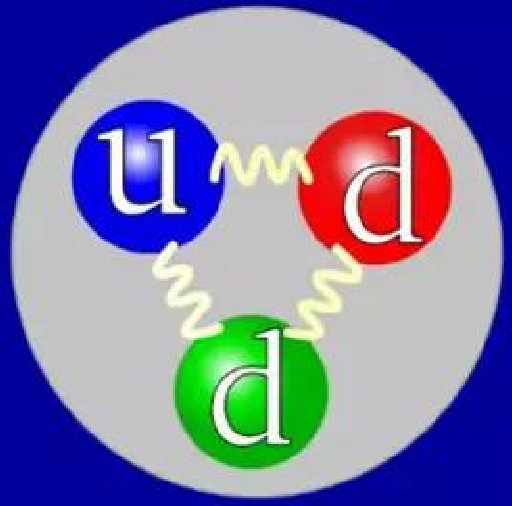
Gas-ant planets: Jupiter not failed star



W-L-S operates on the Sun

Nucleosynthetic process occurs in photosphere, flux tubes, and corona

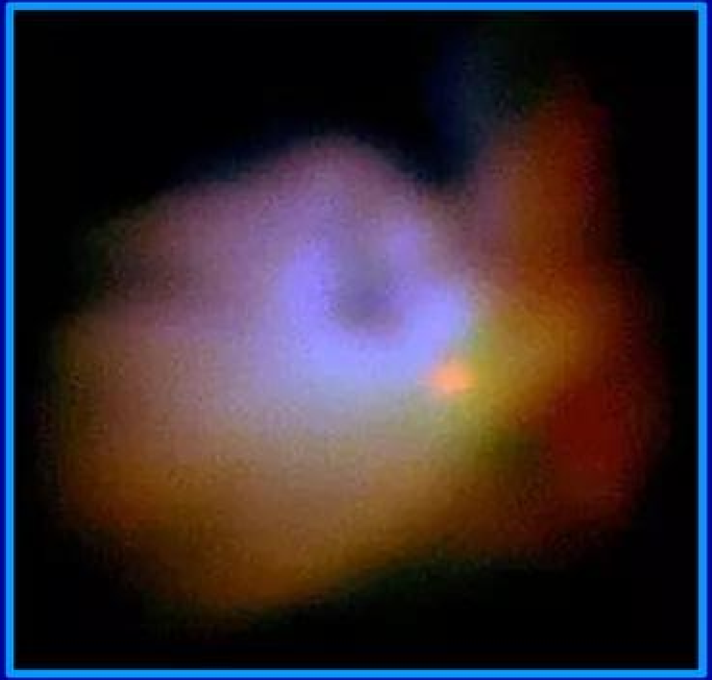
Credit: TRACE image of coronal loops in UV



Quark structure of the neutron - credit: Wikipedia

Very dusty Eagle Nebula

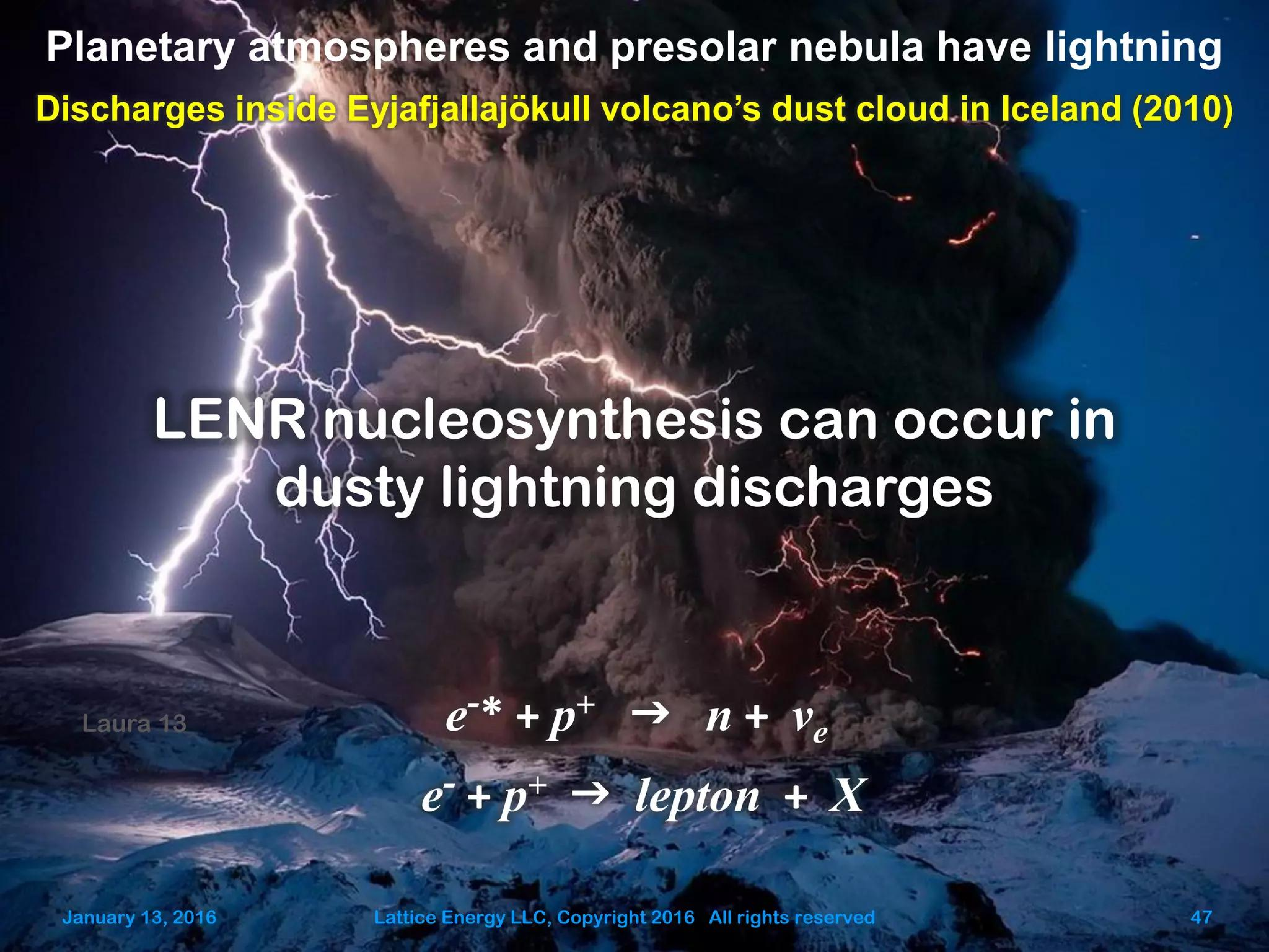
T-Tauri star embedded In nebulosity



White dwarf stars – don't support fusion

Planetary atmospheres and presolar nebula have lightning

Discharges inside Eyjafjallajökull volcano’s dust cloud in Iceland (2010)



Laura 13

LENR nucleosynthesis can occur in dusty lightning discharges

$$e^{-*} + p^{+} \rightarrow n + \nu_{e}$$

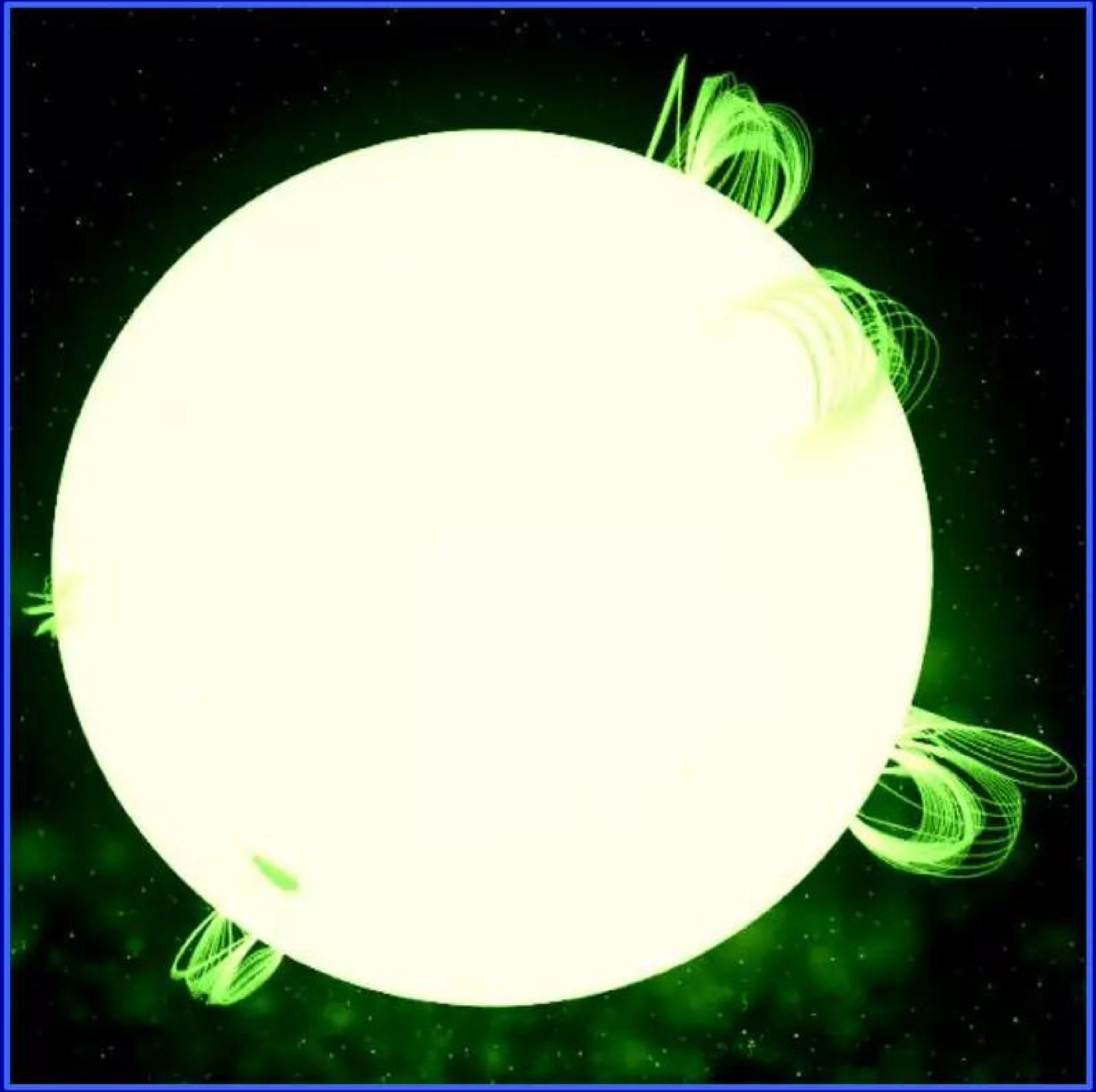
$$e^{-} + p^{+} \rightarrow lepton + X$$

Plasma-filled magnetic flux tubes occur on the Sun

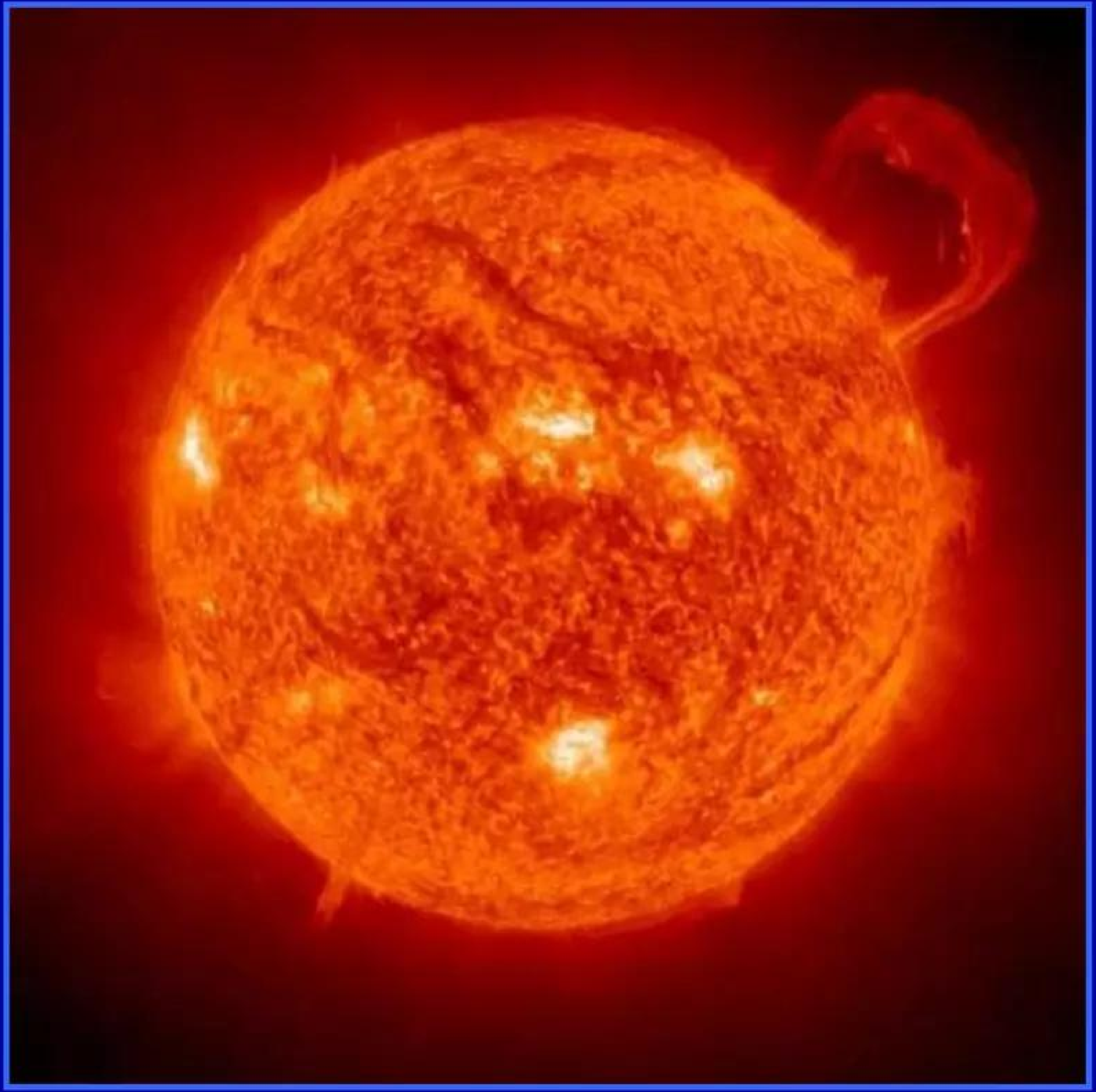
Also called coronal loops; have been observed on other types of stars

These large length-scale ordered magnetic structures quite common in Universe

Idealized graphic of magnetic flux tubes anchored in Sun's surface



Credit: NASA SOHO - false-color image of Sun in extreme ultraviolet



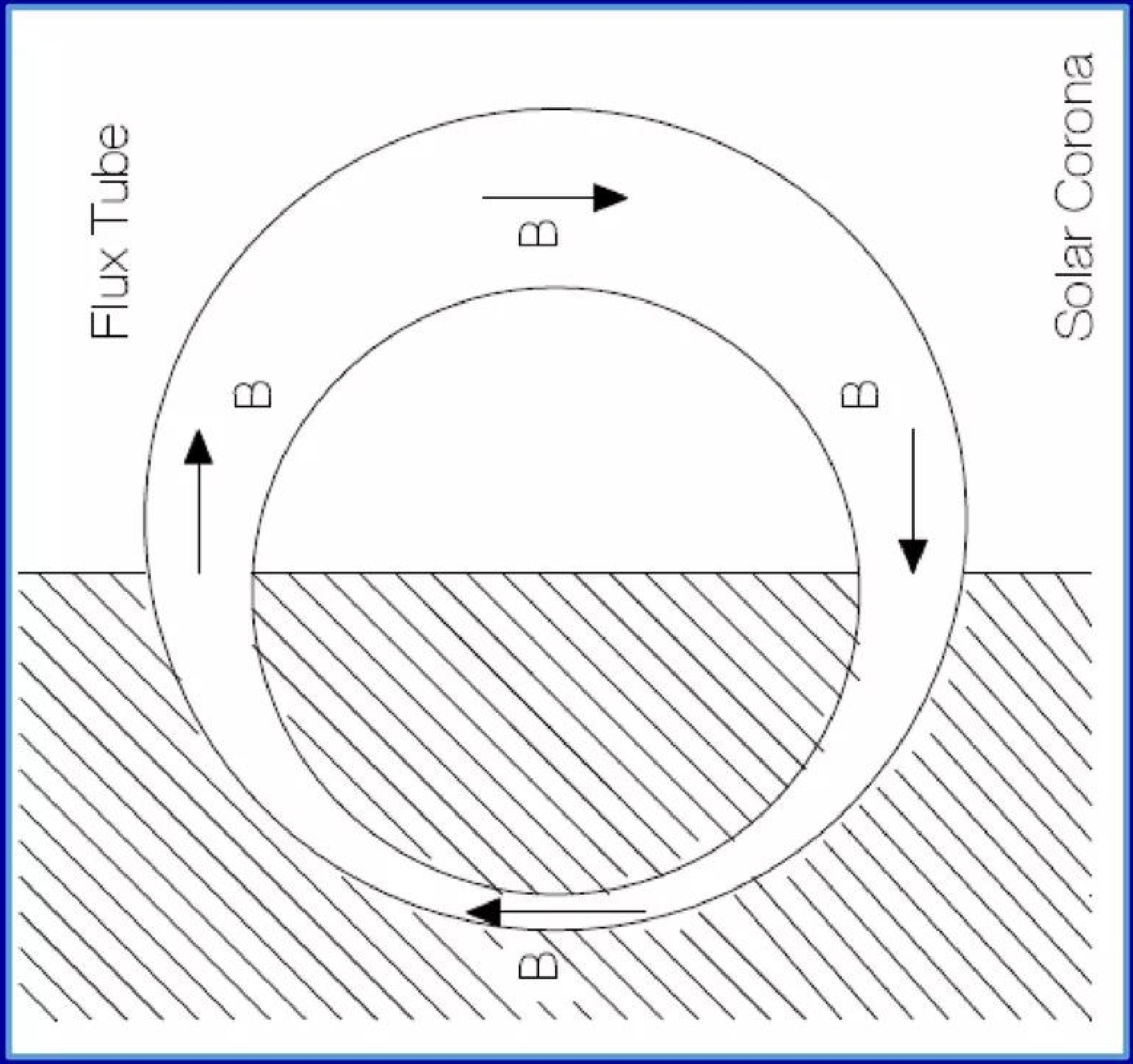
W-L-S posits electroweak $e^- + p^+$ reactions in coronal loops

Mechanism will accelerate protons and electrons in magnetic flux tubes

Neutron production and nucleosynthesis can occur outside dense cores of stars

Widom, Srivastava & Larsen (2008)

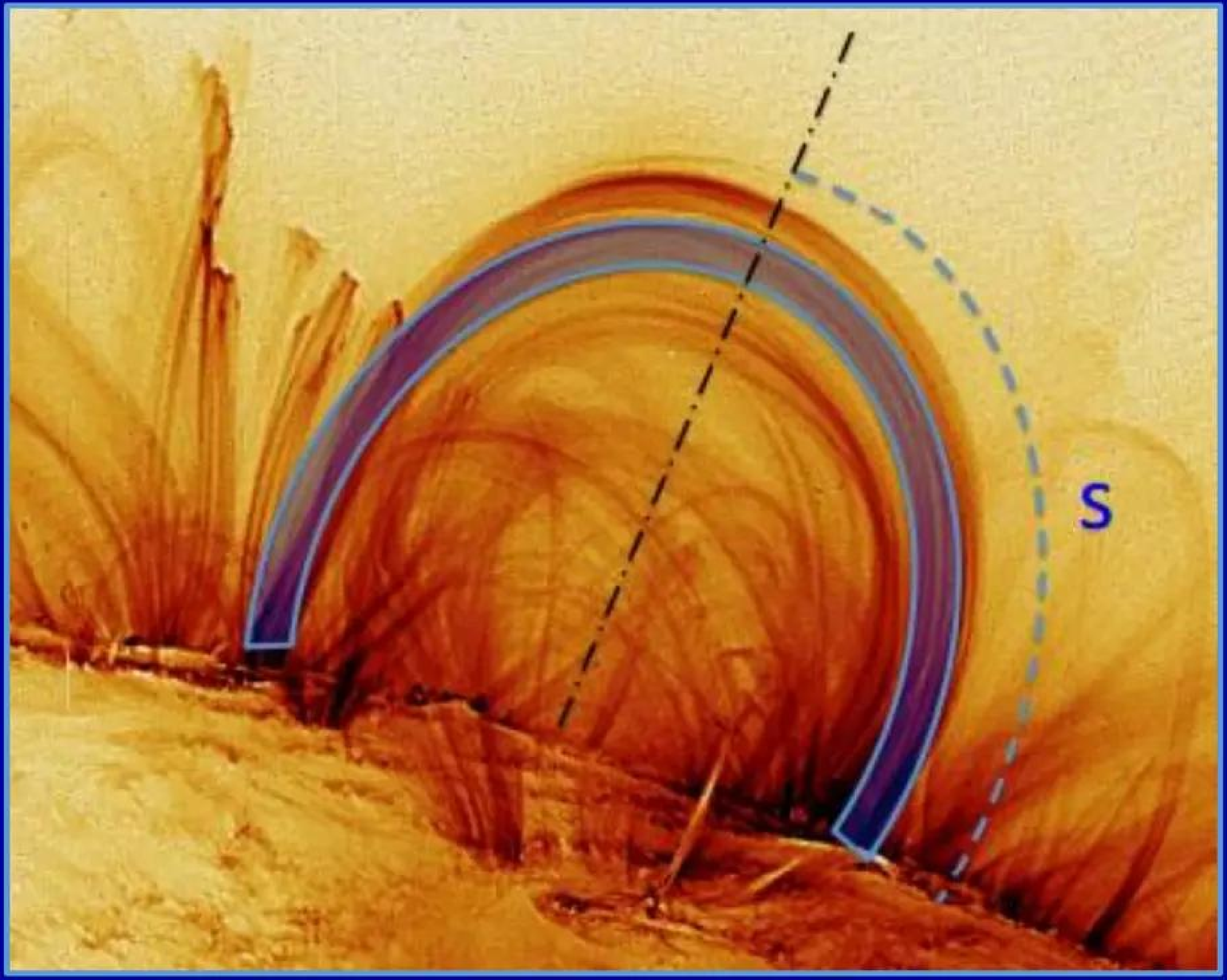
Fig. 1 - Magnetic flux tube



http://arxiv.org/pdf/0804.2647.pdf

F. Reale (2014)

Fig. 12 - Plasma confined in a loop



http://solarphysics.livingreviews.org/Articles/lrsp-2014-4/download/lrsp-2014-4Color.pdf

Many-body collective $e + p$ reactions occur on the Sun

Quoted from: "A primer for electro-weak energy nuclear reactions"

Nucleosynthesis and energetic particle production occurs in magnetic flux tubes

- ✓ "If and when the kinetic energy of the circulating currents in a part of the floating flux tube becomes sufficiently high, the flux tube would become unstable and explode into a solar flare which may be accompanied by a coronal mass ejection. There is a rapid conversion of the magnetic energy into charged particle kinetic energy. These high-energy products from the explosion initiate nuclear as well as elementary particle interactions, some of which have been detected in laboratories."
- ✓ "Recent NASA and ESA pictures show that the surface of the Sun is covered by a carpet-like interwoven mesh of magnetic flux tubes of smaller dimensions.* Some of these smaller structures possess enough magnetic energy to lead to LENRs through a continual conversion of their energy into particle kinetic energy. Occurrence of such nuclear processes in a roughly steady state would account for the solar corona remaining much hotter than the photosphere."
- ✓ "... our picture belies the notion that all nuclear reactions are contained within the core of the Sun."
- ✓ "On the contrary, it provides strong theoretical support for experimental anomalies such as short-lived isotopes that have been observed in the spectra of stars having unusually high average magnetic fields."

* - idea of small loops in 'carpet' is supported by experimental data of H. Peter *et al.*, *A&A* (2013)

Many-body collective *e* + *p* reactions occur on the Sun

W-L-S equations for calculation of center-of-mass acceleration energy

Accelerated particles
center-of-mass energy
for exploding flux tube

$$e\bar{V} \approx (30\ \mathrm{GeV}) \left(\frac{B}{\mathrm{kG}}\right) \left(\frac{\pi R^2}{\Lambda - \mathrm{km}}\right).$$

Eq. (20) in
Pramana paper (2010)

- ✓ In 2008 (*arXiv*) and 2010 (*Pramana*), we derived and published approximate, rule-of-thumb formulas for calculating estimated one-shot, mean center-of-mass acceleration energies for charged particles present in plasma-filled magnetic flux tubes (also called "coronal loops") for two cases: (1) steady-state and (2) explosive destruction of an unstable flux tube (this second case is subset of "magnetic reconnection" processes)
- ✓ These relatively straightforward relationships were discovered in the process of elaborating and extending our theory of many-body collective effects and electroweak reactions involving protons and electrons in condensed matter systems on small length-scales (where short-range, ultra-high strength electric fields dominate) to analogous, much larger-scale electromagnetic systems in which magnetic fields dominate and provide input energy required to drive certain types of electroweak processes, produce pair plasmas, and create elemental nucleosynthesis
- ✓ Our simple equations for magnetic flux tubes are robust and scale-independent. They consequently have broad applicability from exploding wires (which in early stages of explosion comprise dense dusty plasmas), lightning, to solar flux tubes and other astrophysical environments that are characterized by vastly higher magnetic fields; these include many other types of stars besides the Sun, neutron stars, magnetars, and regions located near black holes and active galactic nuclei

Solar flares can produce complex mixtures of products

Many-body collective effects enable electron-proton electroweak reactions

Collective many-body electroweak reactions require input energy

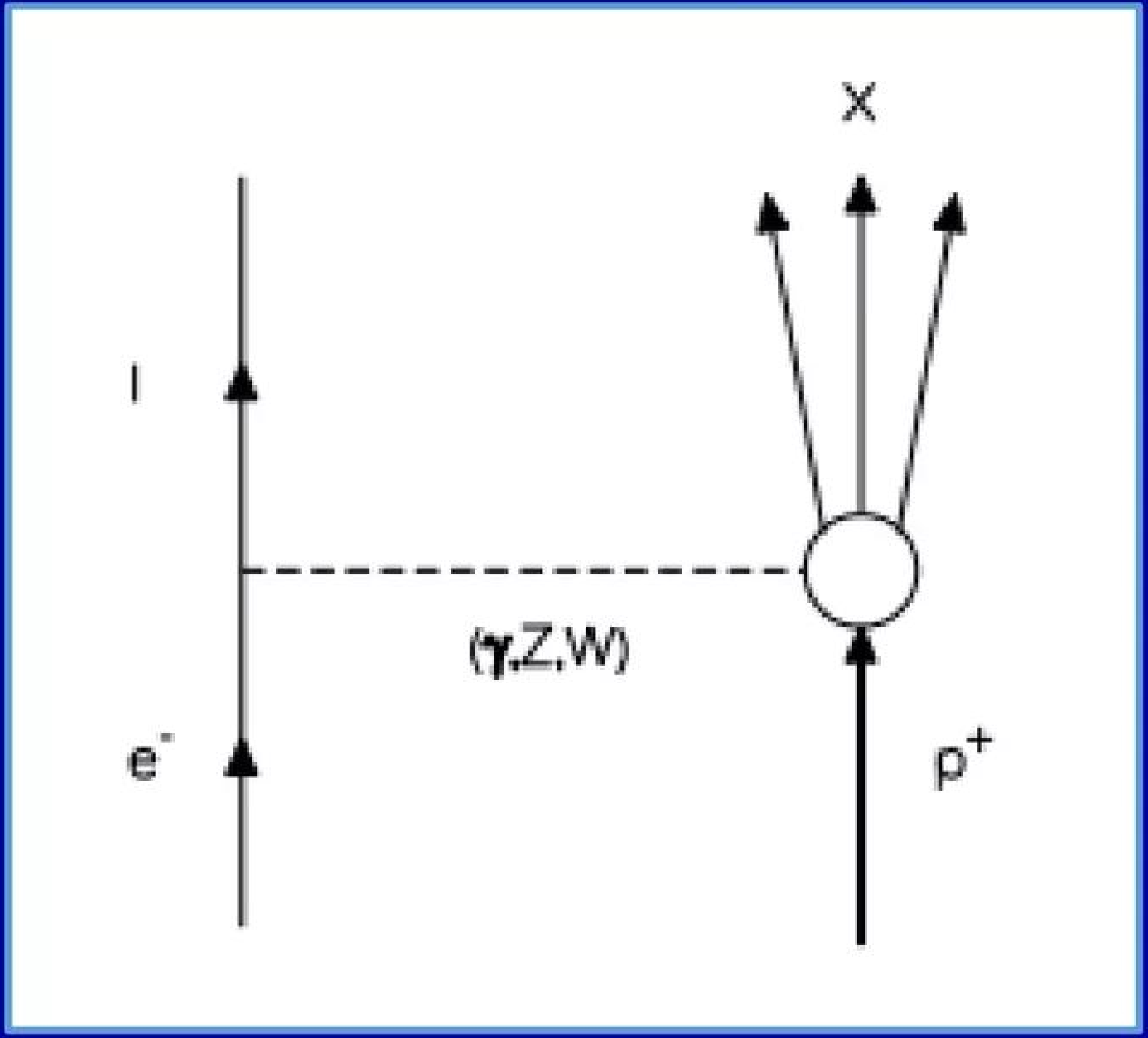
$$e^{-*} + p^{+} \rightarrow n + \nu_e$$
$$e^{-} + p^{+} \rightarrow lepton + X$$

When electric fields dominate

Magnetic fields dominate at very high energies in plasmas

- ✓ FIG.2 shows the electro-weak boson exchange Feynman diagram for electron-proton scattering in colliding electron and proton beams inside a plasma-filled magnetic flux tube at high energies
- ✓ Expression { $e^{-} + p^{+} \rightarrow l + X$ } includes photon γ and Z exchange wherein the final state lepton is an electron for the case of photon γ or Z exchange and the final state lepton is a neutrino for the case of W^{-} exchange. On an energy scale of ~300 GeV, all of these exchange processes have amplitudes of similar orders of magnitude
- ✓ Solar flare or coronal mass ejecting event is thereby accompanied by an increased emission of solar neutrinos over a broad energy scale as well as relativistic protons, neutrons and electrons. Full plethora of final X states including electron, muon and pion particle anti-particle pairs should also be present in such events

FIG. 2: Boson exchange diagrams for electron-proton scattering into a lepton plus "anything"



"High energy particles in the solar corona"
A. Widom, Y. Srivastava, and L. Larsen
arXiv:nucl-th/0804.2647v1 (2008)

Nucleosynthesis occurs in the atmosphere of the Sun

Many-body collective effects enable electron-proton electroweak reactions

Collective many-body electroweak reactions require input energy

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

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

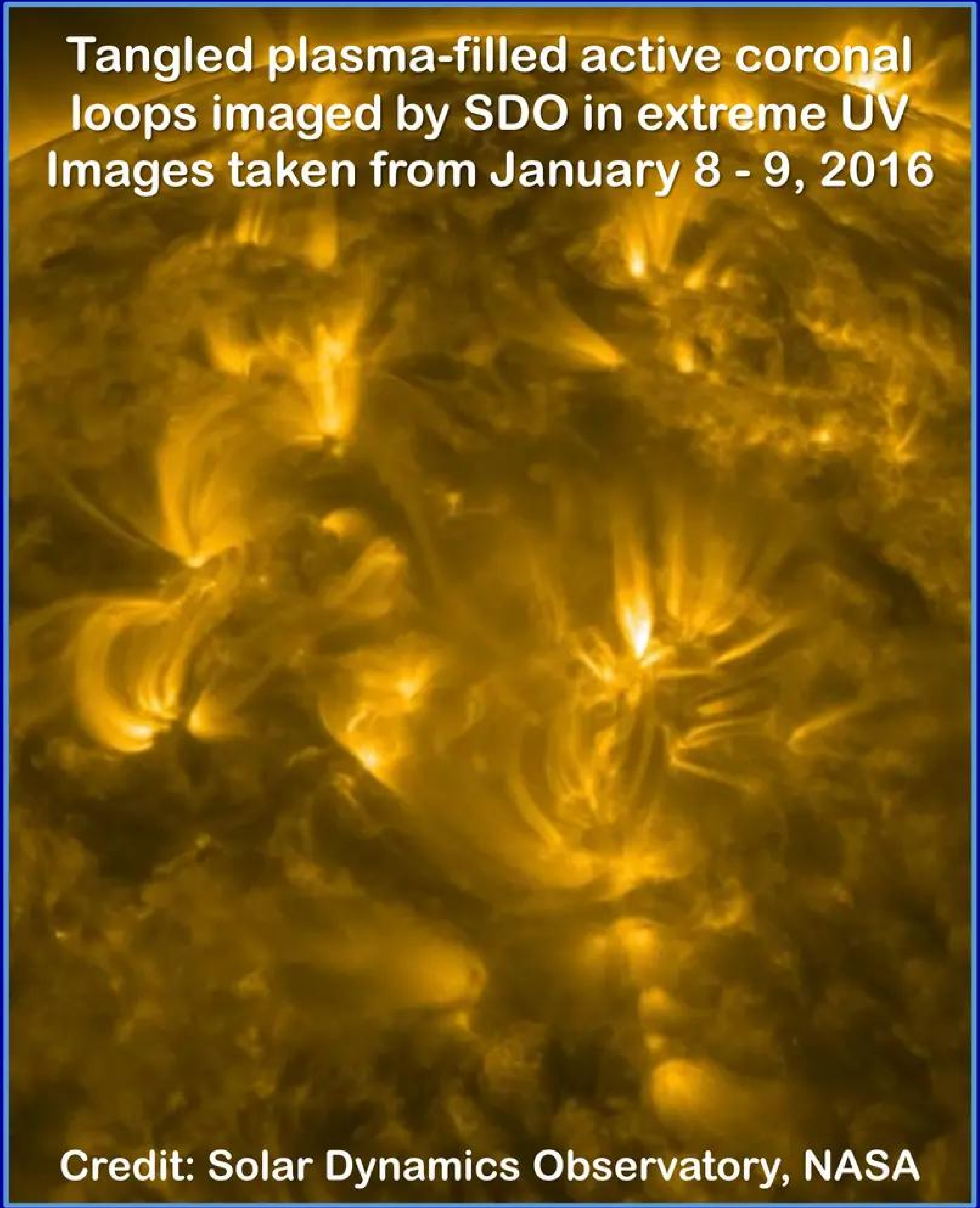
- ✓ Conversion of magnetic field energy into relativistic particle kinetic energy via a Faraday law voltage pulse is collective in that the magnetic flux in the core of the vortex depends on the rotational currents of *all* of the initial protons and electrons
- ✓ "On the energy scale $W_{\text{magnetic}} \ll 300$ GeV of Eq.(13), the weak interaction $p^{+}\ e^{-}$ processes Eq.(7) that produce neutrons proceed more slowly than the purely electromagnetic $p^{+}\ e^{-}$ processes. Nevertheless one finds appreciable neutron production in the solar corona. The production of neutrons among the protons allows for the creation of nuclei with higher mass numbers via neutron capture nuclear reactions and subsequent beta decays." arXiv:nucl-th/0804.2647v1
- ✓ Relativistic neutrons produced by high-energy electroweak $e + p$ reactions in plasma-filled magnetic flux tubes will have low capture cross-sections on seed elements per the 1/v proportionality rule. Nonetheless, neutron-driven nucleosynthesis (albeit at vastly lower rates vs. supernovas) akin to astrophysical *r*- and *s*-processes can occur in and near such commonplace magnetic structures found in varied astrophysical environments including stars' atmospheres, on accretion disks, and near black holes
- ✓ Nucleosynthesis occurs in regions besides stellar cores and supernova explosions

Nucleosynthesis occurs at low rates in coronal loops on Sun

Latest video images of dynamic magnetic flux tubes from NASA's SDO

Go to hyperlink below to see spectacular mp4 video imaging in false-color

http://sdo.gsfc.nasa.gov/assets/gallery/movies/TangledConnections171_big.mp4



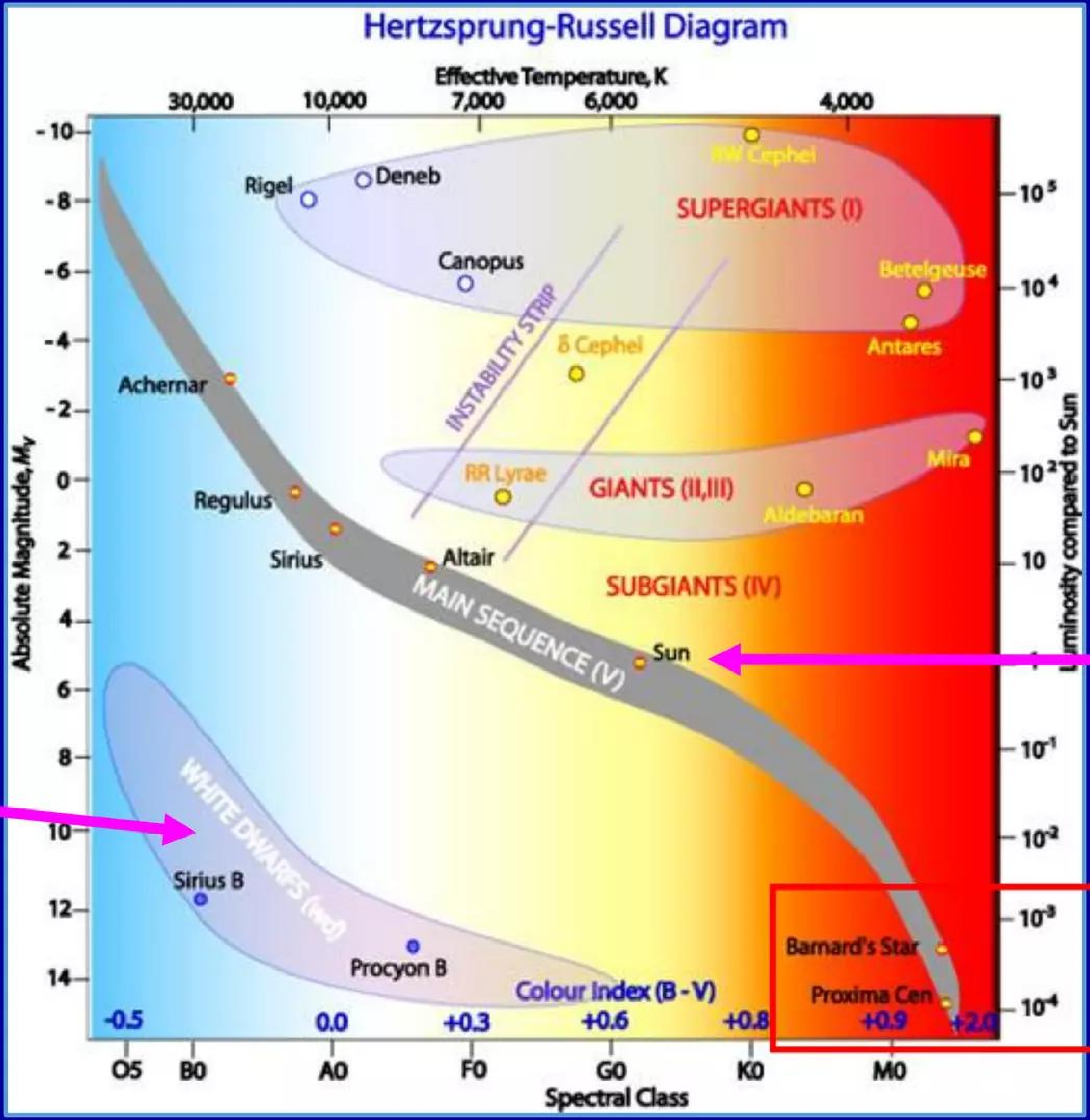
Tangled plasma-filled active coronal loops imaged by SDO in extreme UV Images taken from January 8 - 9, 2016

Credit: Solar Dynamics Observatory, NASA

"When active regions are fairly active and close together, their magnetic field lines connect one region to the other in a tangle of arched lines (Jan. 8-9, 2016). Over a two-day period, we watched as their lines connected, broke apart and reconnected between several other active regions. This activity serves to illustrate the dynamism that is often observed at the Sun's surface. Images were taken in a wavelength of extreme ultraviolet light." - NASA

Ex-core nucleosynthesis at very low rates may be common

Plasma-filled magnetic flux tubes occur on *many* different types of stars

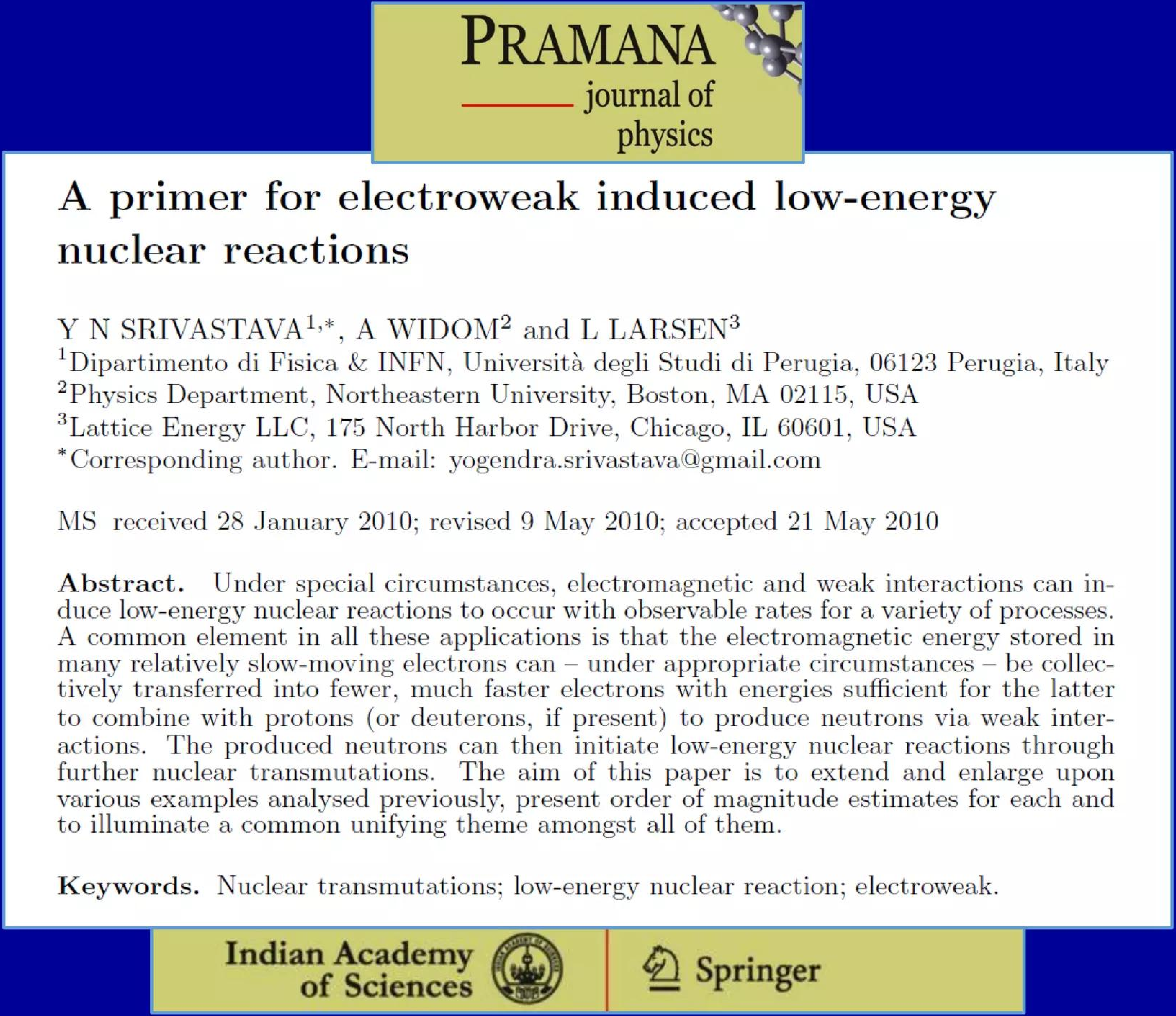


Sun

White dwarfs

Red dwarfs

Credit: CSIRO - Australia Telescope National Facility



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A primer for electroweak induced low-energy nuclear reactions

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Abstract. Under special circumstances, electromagnetic and weak interactions can induce low-energy nuclear reactions to occur with observable rates for a variety of processes. A common element in all these applications is that the electromagnetic energy stored in many relatively slow-moving electrons can – under appropriate circumstances – be collectively transferred into fewer, much faster electrons with energies sufficient for the latter to combine with protons (or deuterons, if present) to produce neutrons via weak interactions. The produced neutrons can then initiate low-energy nuclear reactions through further nuclear transmutations. The aim of this paper is to extend and enlarge upon various examples analysed previously, present order of magnitude estimates for each and to illuminate a common unifying theme amongst all of them.

Keywords. Nuclear transmutations; low-energy nuclear reaction; electroweak.

Indian Academy of Sciences | Springer

Hyperlinked references

Many-body collective effects in condensed matter and magnetic plasmas

Condensed matter

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

Condensed matter

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

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