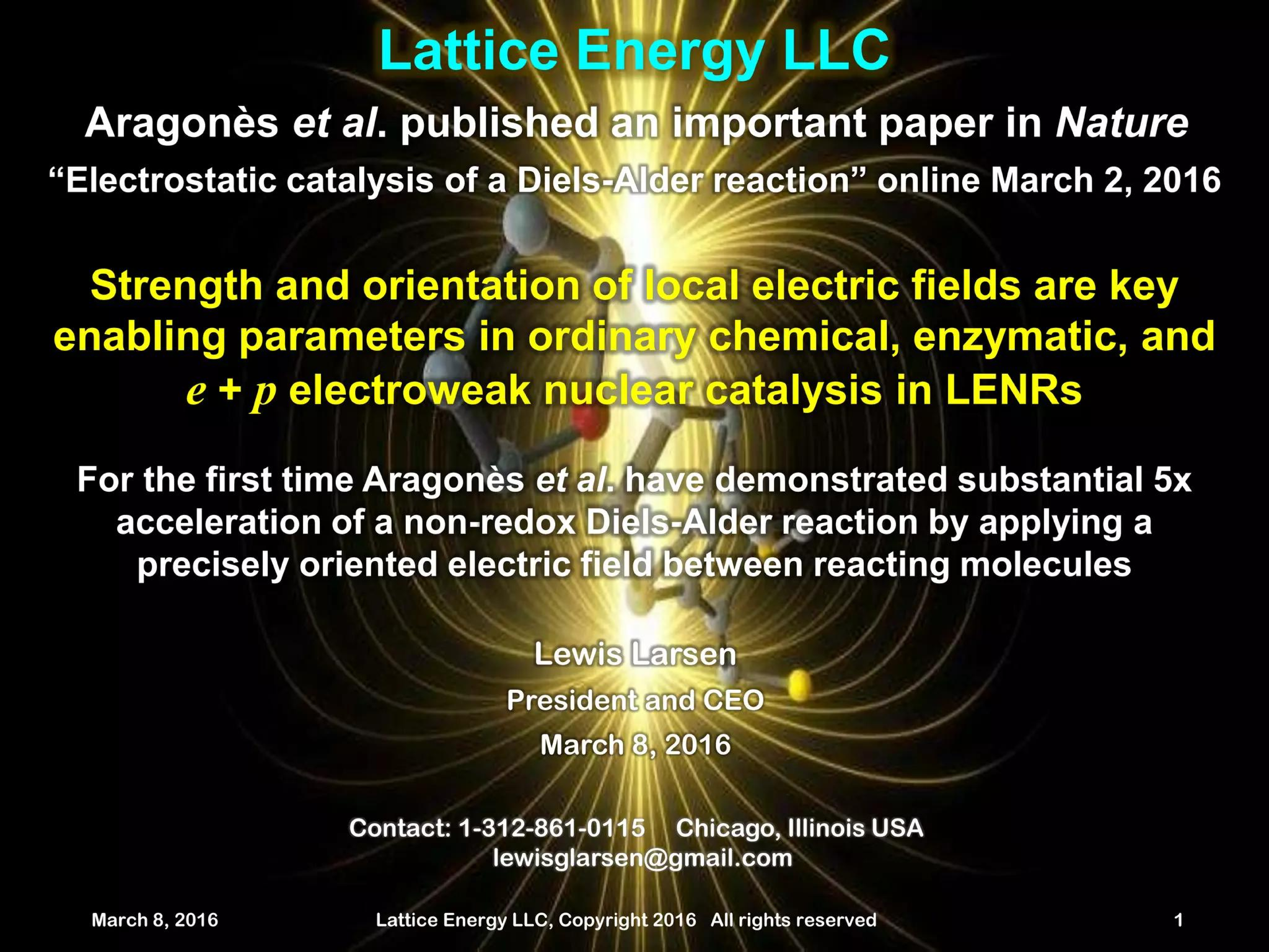


Lattice Energy LLC

Aragonès *et al*. published an important paper in *Nature*

“Electrostatic catalysis of a Diels-Alder reaction” online March 2, 2016

Strength and orientation of local electric fields are key enabling parameters in ordinary chemical, enzymatic, and *e* + *p* electroweak nuclear catalysis in LENRs

For the first time Aragonès *et al*. have demonstrated substantial 5x acceleration of a non-redox Diels-Alder reaction by applying a precisely oriented electric field between reacting molecules

Lewis Larsen
President and CEO
March 8, 2016

Contact: 1-312-861-0115   Chicago, Illinois USA
lewisglarsen@gmail.com

Summary

Chemical catalysis and electroweak nuclear catalysis share certain features

- ✓ Heretofore, chemical and nuclear processes were thought to be vastly distant realms; we now believe that they can happily coexist in close proximity to each other and may interoperate on *nm* to μ length-scales
- ✓ Herein we will argue that there are some very surprising similarities between the operation of active sites in LENR electroweak, enzymatic, and inorganic chemical catalysis: all three can utilize high local electric fields as well as many-body collective quantum effects to achieve dramatic increases in reaction rates and overall catalytic proficiency
- ✓ With respect to LENR active sites vs. those of enzymes and other types of chemical catalysts, what separates chemical from nuclear catalysis could be presence of many-body entangled protons and electrons in close proximity, coupled with input energy that triggers attosecond-scale pulses in local electric fields up to values that are > 2 x 10^{11} V/m
- ✓ It has become clear to Lattice that key knowledge about details of LENR electroweak catalysis may well provide very useful insights into chemical catalysis and vice-versa. We look forward to working with others to exploit this and thus advance technical progress in both areas

Electric field strength and orientation: crucial to catalysis

Very similar catalytic processes occur in chemical and LENR systems

Many-body collective quantum effects help enable catalysis in condensed matter

- ✓ Widom-Larsen theory of ultralow momentum neutron reactions in condensed matter (LENRs) was published in *European Physical Journal C - Particles and Fields* (2006); for first time, we explained how electroweak $e + p$ neutron production and neutron-catalyzed, hard-radiation-free nuclear transmutation reactions can, under exactly the right conditions, occur at very substantial rates in ordinary electrochemical cells
- ✓ According to Widom-Larsen, LENRs in condensed matter are enabled by many-body collective quantum effects that help create nuclear-strength local electric fields above 2×10^{11} V/m that – over attosecond time scales – increase effective surface plasmon electron masses above threshold values that are needed to react directly with local protons to produce long-wavelength neutrons and neutrinos in an electroweak reaction. Prior to Widom-Larsen, that reaction thought to occur only in collapsing stars
- ✓ Based on experimental data collected and published by scientists in Russia back in ~2000, in 2010 we predicted that very high electric fields and many-body collective quantum effects would be very important to operation of active sites in enzymes. This idea was experimentally confirmed by Fried *et al.* in *Science* 346 1510 - 1514 (2014)
- ✓ Extending that same thinking, and joining with other earlier theorists, in early 2015 we also hypothesized that high local electric fields - amongst chemists this is called "electrostatic catalysis" – are important in wide range of catalytic chemical processes. Aragonès *et al.* experimentally confirmed this idea in *Nature* 531 88-91 (March 2, 2016)

Increasing temperature speeds-up chemical reactions

Chemical catalysts boost reaction rates by lowering activation energy

Many-body collective quantum effects can catalyze electroweak nuclear reactions

- ✓ As a very rough rule-of-thumb, for chemical reactions that would ordinarily occur at significant rates at room temperature of ~23° C, the observed reaction rate will approximately double (2x) for every additional ~10° C increase in temperature

- ✓ Raising temperatures will speed-up most chemical reaction rates by increasing numbers of input reactant molecules whose average kinetic energy is greater than the minimum activation energy that is needed to drive a given reaction to completion (found in the high-energy 'tail' of the Maxwell-Boltzmann distribution)

- ✓ Inorganic metallic elements that include among others, Nickel (Ni), Platinum (Pt), Palladium (Pd), can greatly boost rates of some chemical reactions and function as catalysts by substantially lowering the activation energy for certain reactions

- ✓ In course of evolution, living organisms gradually 'learned' how to greatly increase rates of chemical reactions and encoded that information within the collective genome in sequences that specify specialized macromolecules called enzymes; this key advance enabled biological systems to flourish at modest temperatures

- ✓ Akin to enzymes, herein we will see how Nature can utilize many-body collective quantum effects in condensed matter to vastly increase rates of an important type of electroweak neutron-producing reaction that enables variety of star-like nuclear transmutation processes to proceed at substantial rates at modest temperatures

Key characteristics of catalysts for chemical reactions

Primarily increase reaction rates and reduce operating temperatures

Certain metallic elements, zeolites and biomolecular enzymes can be catalysts

- ✓ Enable a given chemical reaction to proceed at a substantially higher rate at a given temperature than if it were not being catalyzed
- ✓ Equivalently, enable high rates of a given chemical reaction to occur at substantially lower temperatures than would be the case if such a catalyst were absent from the system
- ✓ High specificity - catalytic activity is usually restricted to only certain species of reactants and end-products; reduces number of potential side-products and side-reactions for a given accelerated chemical reaction
- ✓ Certain metals, zeolites, and myriad of complex Carbon-based organic molecules called enzyme proteins can function as chemical catalysts
- ✓ Living organisms use enzymes to mediate and speed-up their many metabolic chemical processes and molecular biosynthetic reactions
- ✓ Many types of industrial chemical processes use abiotic metallic catalysts

Aragonès *et al*. published an important paper in *Nature*

"Electrostatic catalysis of a Diels-Alder reaction"
A. Aragonès *et al*. *Nature* 531 pp. 88 - 91 (March 3, 2016)

http://www.nature.com/nature/journal/v531/n7592/full/nature16989.html

"It is often thought that the ability to control reaction rates with an applied electrical potential gradient is unique to redox systems. However, recent theoretical studies suggest that oriented electric fields could affect the outcomes of a range of chemical reactions, regardless of whether a redox system is involved. This possibility arises because many formally covalent species can be stabilized via minor charge-separated resonance contributors. When an applied electric field is aligned in such a way as to electrostatically stabilize one of these minor forms, the degree of resonance increases, resulting in the overall stabilization of the molecule or transition state. This means that it should be possible to manipulate the kinetics and thermodynamics of non-redox processes using an external electric field, as long as the orientation of the approaching reactants with respect to the field stimulus can be controlled. Here, we provide experimental evidence that the formation of carbon–carbon bonds is accelerated by an electric field. We have designed a surface model system to probe the Diels–Alder reaction, and coupled it with a scanning tunnelling microscopy break-junction approach. This technique, performed at the single-molecule level, is perfectly suited to deliver an electric-field stimulus across approaching reactants. We find a fivefold increase in the frequency of formation of single-molecule junctions, resulting from the reaction that occurs when the electric field is present and aligned so as to favour electron flow from the dienophile to the diene. Our results are qualitatively consistent with those predicted by quantum-chemical calculations in a theoretical model of this system, and herald a new approach to chemical catalysis."

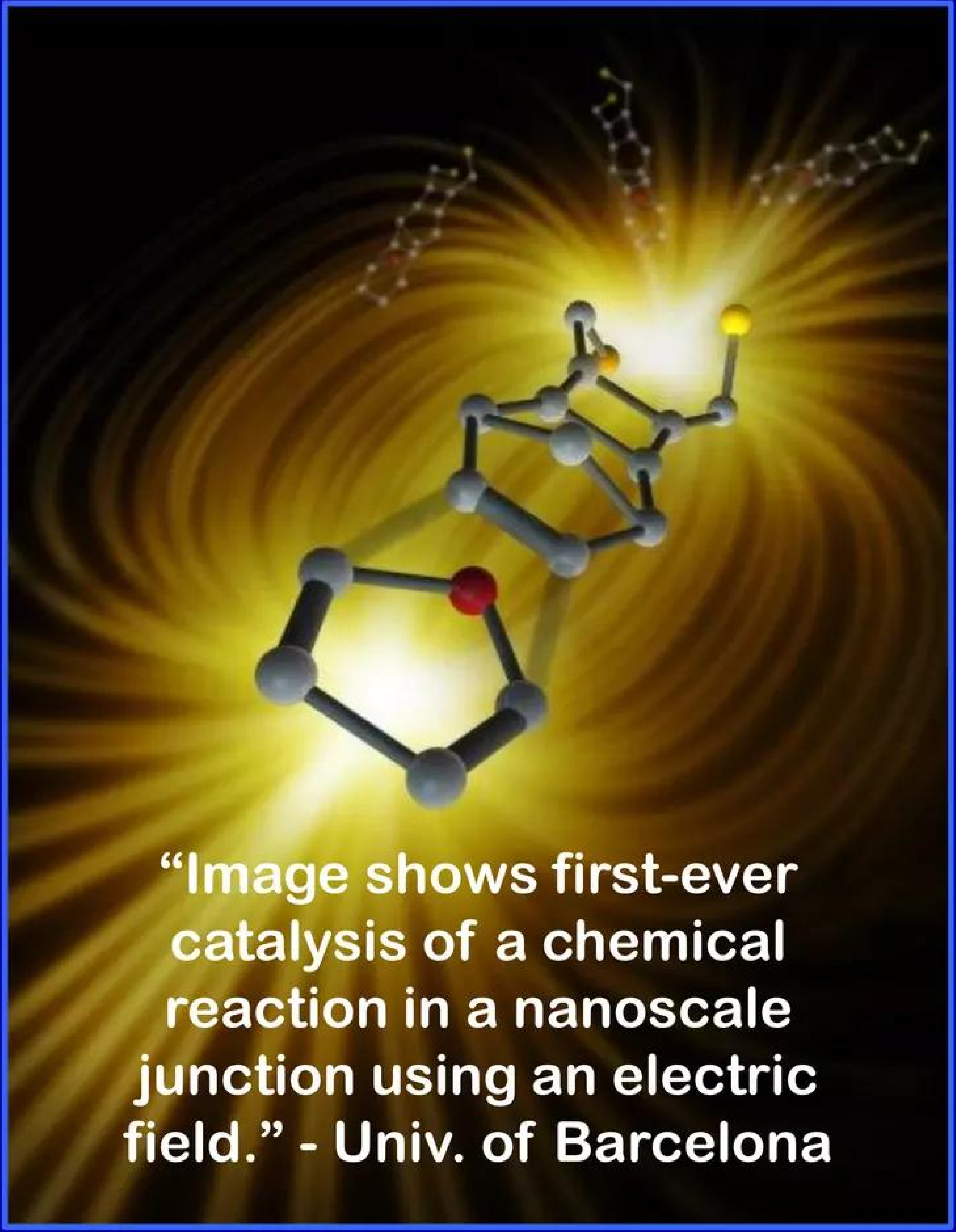
Aragonès *et al*. published an important paper in *Nature*

nature International weekly journal of science

http://www.nature.com/nature/journal/v531/n7592/full/nature16989.html

Quoting the Editor's summary:

"Theory suggests that many chemical reactions — not simply, as is often thought, redox reactions — might be catalysed by an applied electrical field. Experimental evidence for this is now provided from single-molecule studies of the formation of carbon–carbon bonds in a Diels-Alder reaction. In a series of scanning tunneling microscopy break-junction experiments, the authors observe a fivefold increase in the frequency of single-molecule junction formation when the electrical field is present and aligned in the direction to favour electron flow from the dienophile to the diene. The demonstration that it is possible to manipulate chemical reactions with electric fields offers proof-of-principle for a novel approach to heterogeneous catalysis."

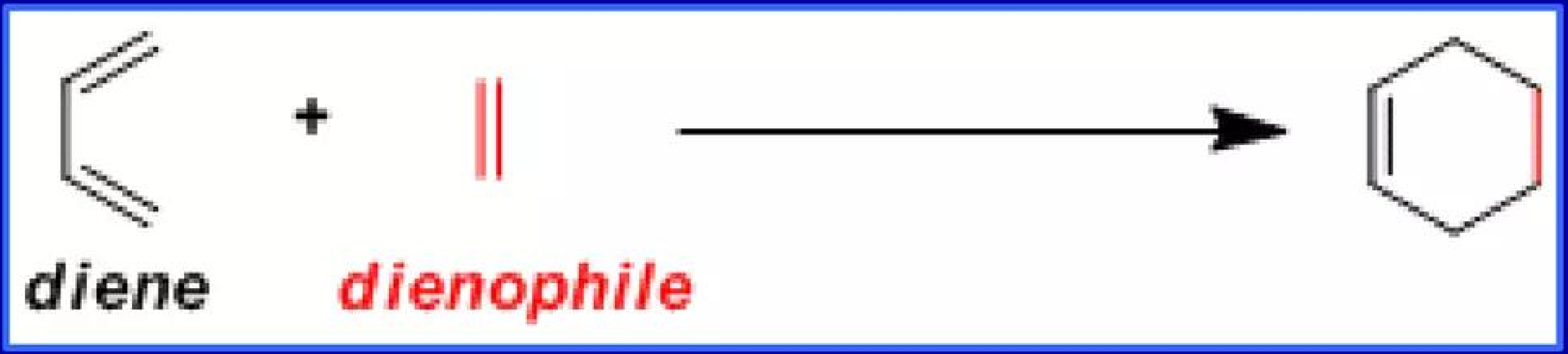


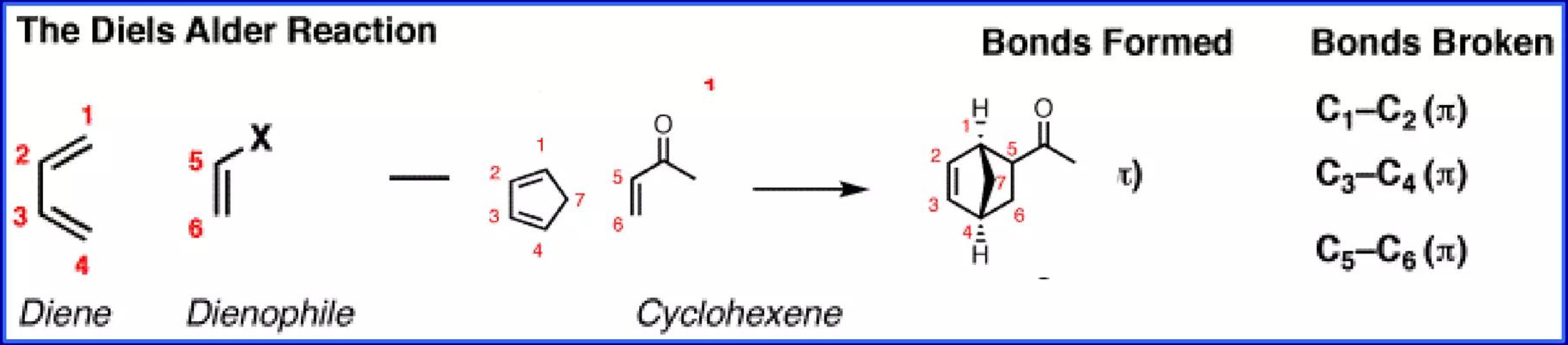
"Image shows first-ever catalysis of a chemical reaction in a nanoscale junction using an electric field." - Univ. of Barcelona

Diels-Alder reaction

"Diels Alder reaction converts a diene and an alkene (usually electron-poor, called a "dienophile") into a six-membered ring containing an alkene (cyclohexene)."

Master Organic Chemistry




The Diels Alder Reaction

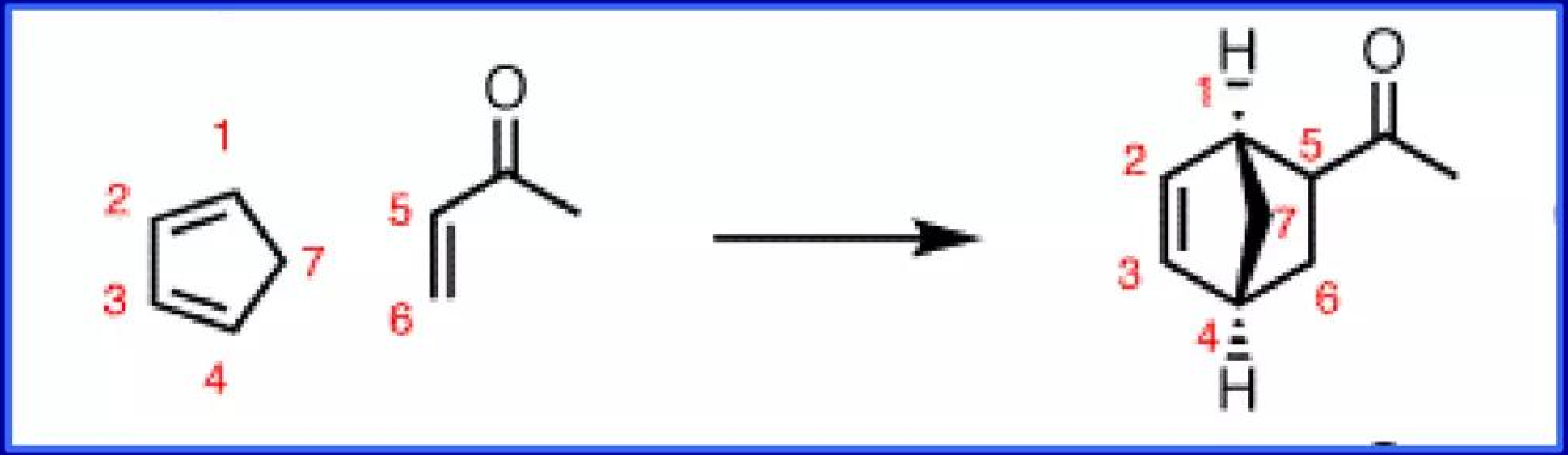
Bonds Formed

Bonds Broken

C_1–C_2 (π)

C_3–C_4 (π)

C_5–C_6 (π)



http://www.masterorganicchemistry.com/reaction-guide/diels-alder-reaction-of-dienes-and-dienophiles/

Commentary on new *Nature* paper by Aragonès *et al*.

"UB scientists exploit nanotechnology approaches to speed up chemical reactions"
March 3, 2016 [excerpts from news story below]

http://www.ub.edu/web/ub/en/menu_eines/noticies/2016/03/005.html

Researchers at the University of Barcelona (UB) and two universities in Australia have introduced a new way of catalyzing - speeding up - chemical reactions by applying an electric field between the reacting molecules.

"Theory suggested that many chemical reactions – and not just redox (electron transferring) reactions, as is often thought – might be catalysed by applying an electric field," says Ismael Díez-Pérez, assistant professor at the University of Barcelona and senior researcher at IBEC, who led the study published in *Nature* today. "We've provided experimental evidence for this for the first time."

Electrostatic catalysis (the use of electric fields) is the least developed form of catalysis in synthetic chemistry, because electrostatic effects are strongly directional. The researchers in Spain and Australia overcame this by using state-of-the-art single molecule techniques that are based on scanning tunneling microscopy. "Our modified STM approach allows recording direct signatures of individual molecules reacting", says Albert Cortijos, a FPU-PhD candidate at UB. "By controlling the orientation of the molecules with respect to the electric field, we accelerated a non-redox reaction for the first time," adds Ismael. Adds Nadim Darwish, a Marie Curie Research Fellow at UB, "This opens the door for future chemical technology".

Commentary on new *Nature* paper by Aragonès *et al*.

"Scientists control chemical reactions with static electricity" March 3, 2016 **[excerpts from news story below]**

http://www.ub.edu/web/ub/en/menu_eines/noticies/2016/03/005.html

The team used an electric field as a catalyst for a common reaction, the Diels-Alder reaction, improving its reaction rate by a factor of five.

Lead researcher Professor Michelle Coote from ANU Research School of Chemistry said the team had overturned conventional thinking with their new-found control of the common reaction, which is used to make a range of chemicals from self-healing materials to the drug cortisone. **"It's the most unexpected result possible," said Professor Coote,** who is also a Chief Investigator with ARC Centre of Excellence for Electromaterials Science (ACES). **"We now have a totally new way of thinking about chemistry.** The breakthrough could speed up manufacturing processes and allow unprecedented control of chemical reactions … " she said.

An electric field catalyst is completely different to conventional catalysts. As electric fields can be turned on and off very quickly from outside the test-tube, the new approach gives the researchers remote control over chemical processes. Professor Coote predicted that electric fields could strongly affect reaction rates, but it had never been observed before because standard chemical reactions are conducted with molecules oriented in random directions in a gas or liquid.

LENRs and chemical catalysis are similar in key ways

- ✓ Similar to what happens in stars, LENRs are neutron-induced nuclear transmutation reactions that produce heavier stable elements from neutron captures on lighter ones. Unlike stars and fission reactors, LENRs do not emit any deadly MeV radiation; they occur in laboratory devices as well as at low rates in Nature elsewhere on Earth
- ✓ In LENRs, star-like nucleosynthesis of elements occurs under mild macroscopic conditions; e.g. at as little as room temperature and atmospheric pressure. This enzyme-like feat is possible with electroweak catalysis that creates ultralow-energy neutrons via many-body collective quantum effects in a direct reaction: $e + p \rightarrow n + \nu_e$
- ✓ Peer reviewed Widom-Larsen theory of ultralow energy neutron reactions (LENRs) in condensed matter systems enables a clear understanding and provides detailed conceptual descriptions of *nm*- to *μ*-scale LENR active sites that form on surfaces, at certain types of interfaces, on hydrogenated Carbon aromatic rings, and even on graphene under particular sets of physical conditions specified in detail by theory
- ✓ W-L theory posits: mutual quantum-mechanical (Q-M) entanglement of many-body collections of charged particles (protons and electrons) and nuclear-strength local electric fields are crucial to operation of LENRs in condensed matter. Herein we will discuss how high electric fields and mesoscopic Q-M entanglement are also quite important in the operation of biological enzymes and that there are very surprising similarities between how LENR-active sites operate and enzymatic biocatalysis

Characteristics of LENR and chemical catalytic active sites

Parameter	Characteristics of catalytically active sites that greatly increase reaction rates		
Energy scale	Nuclear - keV up to multiple MeVs	Chemical - up to several eVs or thereabouts	
Type of system	Electroweak catalysis in condensed matter	Biological enzyme	Inorganic chemical
Are extremely high local electric fields important?	Yes, it is crucial to electroweak catalysis of LENRs in condensed matter at ~STP	Yes, see Fried *et al.* *Science* (2014)	Sometimes
Are many-body collective effects important?	Yes, it is crucial to electroweak catalysis of LENRs in condensed matter at ~STP	Yes, see Herschlag *et al.*, *Biochem*. (2013)	Sometimes
Is quantum mechanical entanglement of protons (Hydrogen) important?	Yes, adsorbed H in surface active sites and H on aromatic rings that rest on surfaces, including metals, fullerenes, graphene	Yes, see Wang *et al.* *PNAS* (2014)	Yes, H adsorbed on surfaces or at interfaces
Quantum mechanical entanglement of electrons?	Yes, amongst surface plasmons and π electrons found on aromatic rings	Yes, π electrons on Carbon aromatic rings	Yes, with surface plasmons
Any deadly MeV-energy gamma emissions?	None: heavy-mass electrons convert γ to safe infrared per US Patent #7,893,414 B2	None	None
Any deadly MeV-energy neutron emissions?	None: almost all are captured locally; see Widom & Larsen, *EPJC* (2006)	None	None
Extreme specificity for reactants and products?	Yes, $e + p$ or $e + d$ or $e + t$ → [1, 2, or 3] $n + \nu_e$ (neutron, neutrino)	Yes, extremely	Somewhat; can vary greatly
Is catalytically active site conserved and reusable?	No, exists for ~200 to 400 nanoseconds and then Q-M coherence thermally destroyed	Yes, essentially unchanged and viable	Mostly, for a while
Are species of chemical elements conserved in catalytic process?	No, relative isotopic ratios of stable elements can shift; species and quantities of chemical elements present can change	Yes, all species of chemical elements are fully conserved, i.e. do not change; when measurable, isotopic shifts should always mass-balance	

Widom-Larsen theory can explain LENRs on surfaces

Electromagnetic (E-M), chemical, and nuclear processes interoperate

Crucial role of surface plasmon electrons makes E-M resonances very important

- ✓ According to Widom-Larsen, chemical and nuclear processes actively coexist and sometimes may even interoperate on condensed matter surfaces
- ✓ In condensed matter systems, LENRs involve very complex interactions between surface plasmon (SP) or molecular π electrons, E-M fields, and myriad of different nanostructures that can have varied geometries, surface locations relative to each other, different-strength local E-M fields, and varied chemical or isotopic compositions
- ✓ To varying degrees, many of these complex, time-varying surface interactions are electromagnetically coupled to each other on different physical length-scales: thus, mutual E-M resonances on nanometer scales can be very important in LENR systems
- ✓ Besides optical frequencies, SP and/or π electrons in condensed matter systems may have absorption and emission bands in infrared (IR) and UV regions of spectrum
- ✓ For example, some regions on a given surface may be absorbing E-M energy locally, while others nearby can be emitting energy (e.g., as energetic electrons, photons, other charged particles, etc.). At same time, SPs can transfer energy laterally from regions of resonant absorption or capture to other regions in which energy emission or consumption is taking place: e.g., photon or electron emission and to drive LENRs

Widom-Larsen theory of ultralow energy neutron reactions

Three key publications that begin in March of 2006 are referenced below

Many-body collective effects enable electroweak catalysis in condensed matter

"Ultra low momentum neutron catalyzed nuclear reactions on metallic hydride surfaces"
A. Widom and L. Larsen
***European Physical Journal C - Particles and Fields* 46 pp. 107 - 112 (2006)**

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

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

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

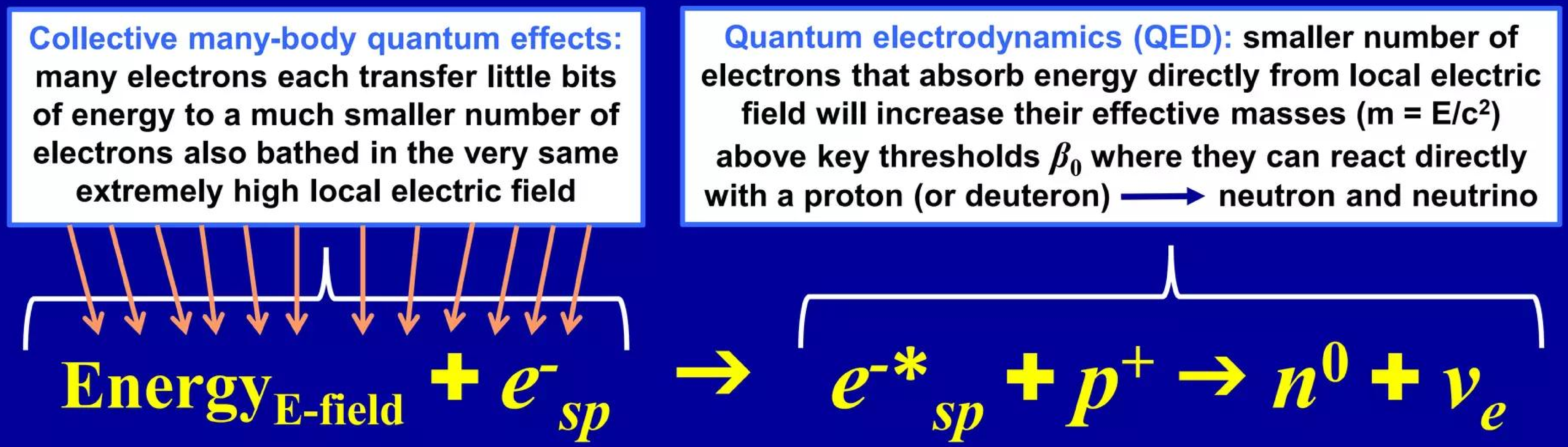
"A primer for electro-weak induced low energy nuclear reactions"
Y. Srivastava, A. Widom, and L. Larsen
***Pramana - Journal of Physics* 75 pp. 617 - 637 (2010)**

http://www.slideshare.net/lewisglarsen/srivastava-widom-and-larsenprimer-for-electroweak-induced-low-energy-nuclear-reactionspramana-oct-2010

Electroweak reaction in Widom-Larsen theory is simple

Protons or deuterons react directly with electrons to make neutrons

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



Draw energy from electric fields > 10^{11} V/m

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

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

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

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

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

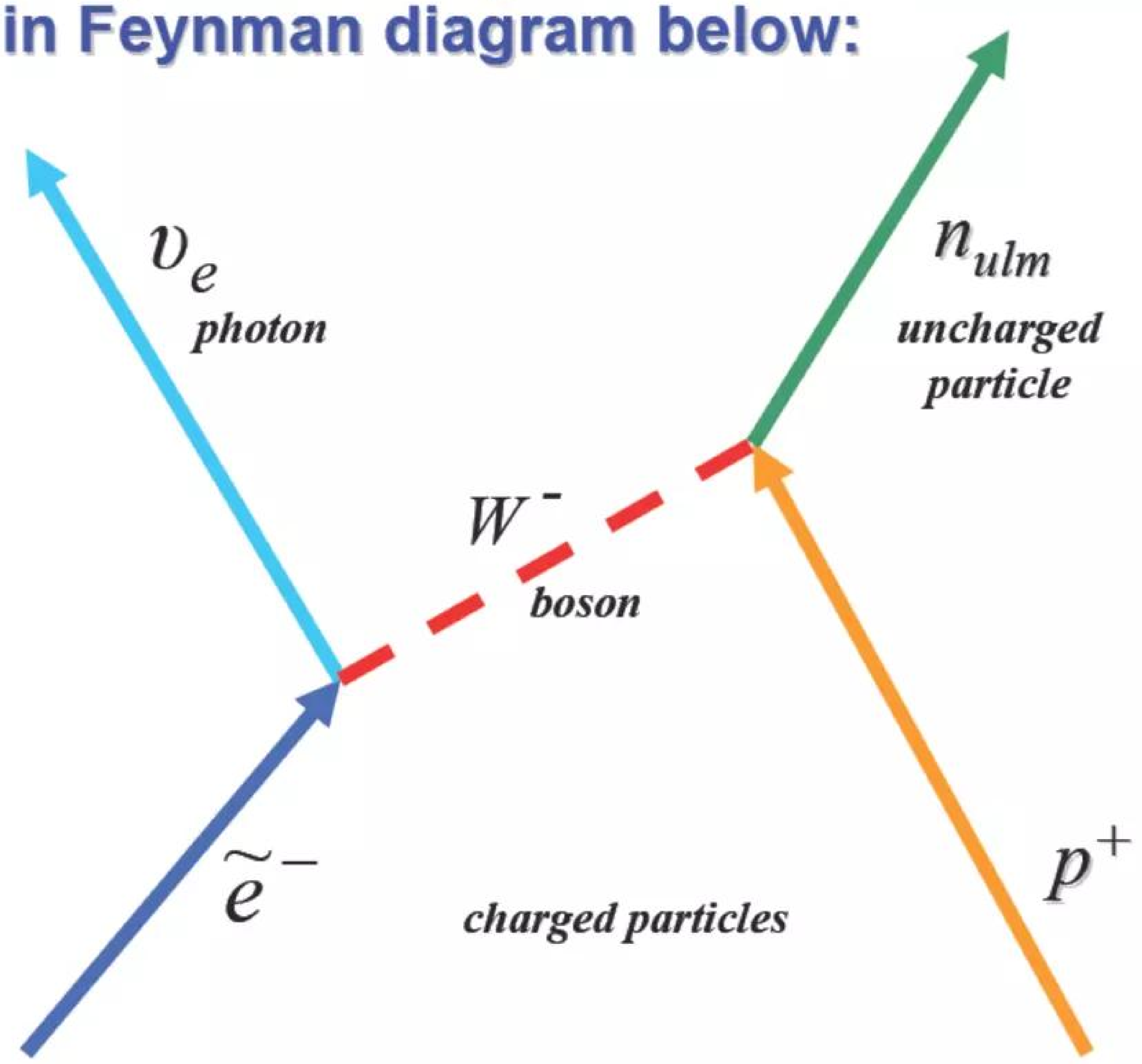
$$\text{Neutrons + atomic nuclei} \xrightarrow{\text{Induce transmutation}} \text{heavier elements + decay products}$$

Many-body collective quantum effects crucial to LENRs

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

Condensed matter many-body collective effects involve quantum entanglement

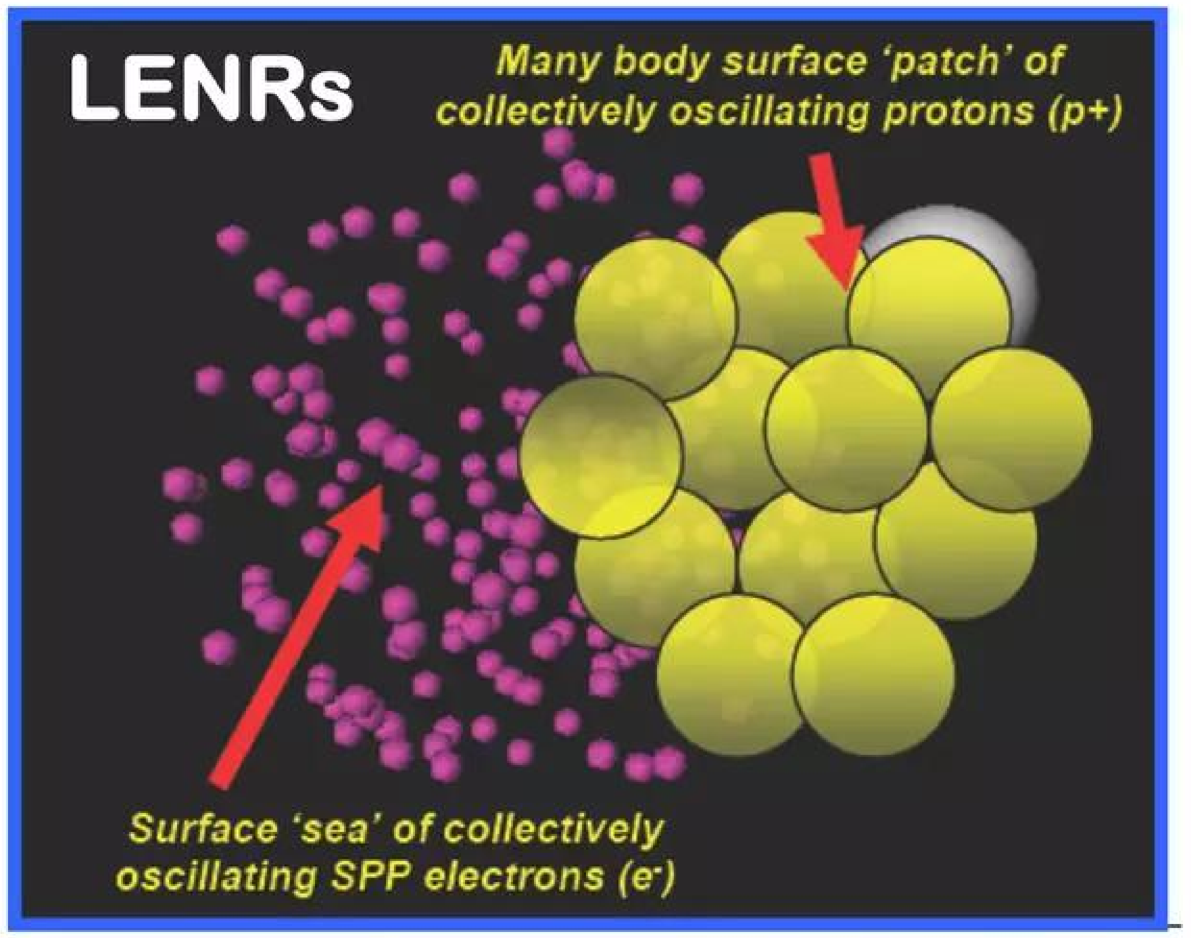
Simple two-body collision shown in Feynman diagram below:



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

What really happens is many-body

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



Above is what really occurs on metallic hydride cathodes

LENR catalysis boosts electroweak *e* + *p* reaction rate

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

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

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

- ✓ In coherently oscillating. Q-M entangled patches of surface protons, deuterons, or tritons the Born-Oppenheimer approximation breaks down; this causes local electromagnetic coupling between surface plasmon (SP) electrons and protons, deuterons, or tritons associated/entangled with an LENR many-body active site and enables transient, nuclear-strength, collective local electric fields > 2 x 10^{11} V/m to be created therein. Such a site is conceptually akin to a gigantic 'naked' pancake-shaped, micron⁺ diameter atomic nucleus resting on top of a substrate surface
- ✓ LENR active site SP electrons locally bathed in nuclear-strength electric fields undergo a phenomenon called "mass renormalization" whereby their masses effectively increase. This effect, upon which the W-L theory of LENR electroweak catalysis relies, was first discovered and published by famous Russian physicists in 1970s (Landau & Lifshitz, "The Classical Theory of Fields", Sects. 17 and 47, Prob. 2, Pergamon Press, Oxford 1975 and Berestetskii, Lifshitz, & Pitaevskii, "Quantum Electrodynamics", Sect. 40, Eq. 40.15, Butterworth Heinmann, Oxford, 1997). Effect is uncontroversial and well-accepted among high-energy particle physicists
- ✓ Since such electrons are not increasing mass via kinetic energy associated with high-velocity translational motion, no bremsstrahlung radiation will be produced

W-L LENR theory identifies ideal types of input energy

External source of input energy required to produce LENR neutrons

Charged-particle currents and electromagnetic photons are ideal energy inputs

- ✓ LENR active sites must be subjected to external non-equilibrium fluxes of charged particles or electromagnetic (E-M) photons that are able to transfer input energy directly to many-body SP or π electron surface 'films'. Examples of external energy sources include (they may be used in combination): electric currents and/or rapidly oscillating electric fields; E-M photons emitted from coherent lasers or incoherent IR-resonant E-M cavity walls, etc.; pressure gradients of p^+, d^+, and/or t^+ ions imposed across site surfaces; currents of other ions crossing SP electron 'film' in either direction (i.e., ionic fluxes); etc. Such sources can provide input energy required to surpass certain minimum H-isotope-specific enhanced electron-mass thresholds that allow production of ultralow energy neutron fluxes via many-body collective $e^* + p^+$, $e^* + d^+$, or $e^* + t^+$ electroweak LENR reactions
- ✓ N.B. please note again that surface plasmons (SP) are collective, many-body electronic phenomena closely associated with interfaces. For example, they can exist at gas/metal interfaces or metal/oxide interfaces. Thus, surface plasmon oscillations will almost certainly also be present at contact points between purely metallic surfaces and adjacent layers and/or nanoparticles composed of metallic oxides, e.g., PdO, NiO, or TiO_2, etc., or vice-versa
- ✓ Formation of new catalytically active LENR sites ceases when input energy stops

W-L theory explains creation of LENR-active sites

Needed to produce neutrons that induce transmutation of elements

Hydrogen (protons or deuterons) and heavy-mass electrons are key reactants

- ✓ Substantial quantities of Hydrogen isotopes must be brought into intimate contact with fully-H-loaded metallic hydride-forming metals (or non-metals like Se); e.g., Palladium, Platinum, Rhodium, Nickel, Titanium , Tungsten, etc. Please note that collectively oscillating, 2-D surface plasmon (SP) electrons are intrinsically present and cover the surfaces of such metals. At full lattice loading (saturation) of Hydrogenous isotopes, many-body, collectively oscillating island-like LENR active sites comprised of protons p^+, deuterons d^+, or tritons t^+ will form spontaneously at random locations on such surfaces
- ✓ Or, delocalized collectively oscillating π electrons that comprise the outer covering surfaces of fullerenes, graphene, benzene, and polycyclic aromatic hydrocarbon (PAH) molecules behave identically to SPs; when such molecules are hydrogenated, they can create many-body, collectively oscillating, entangled quantum systems that per W-L theory are functionally equivalent molecular analogues of metal hydrides. In this case, LENRs are triggered on aromatic rings; strong tendency to transmute ring Carbon atoms
- ✓ Born-Oppenheimer approximation breaks down in LENR active sites composed of nearly homogenous collections of collectively oscillating p^+, d^+, and/or t^+ ions; this enables E-M coupling between nearby SP or π electrons and hydrogen ions at active sites and creates nuclear-strength local electric fields > 2 x 10^{11} V/m. Effective masses of electrons in such E-fields are increased to a multiple of an electron at rest ($e \rightarrow e^*$) determined by required ~simultaneous energy input(s); this is called “mass renormalization” by particle physicists

Local breakdown of Born-Oppenheimer approximation

Key to LENR electroweak catalysis: enables huge local electric fields

In nm to *μ*-scale regions B-O breakdown enables E-fields > 2 x 10^{11} V/m threshold

- ✓ Breakdown of Born-Oppenheimer approximation well-established as occurring under certain conditions in various types of systems; measured experimentally
- ✓ See: A. Bushmaker *et al.*, "Direct observation of Born-Oppenheimer approximation breakdown in carbon nanotubes" *Nano Letters* 9 pp. 607 (2009)
  http://core.ac.uk/download/pdf/4881613.pdf
- ✓ Well-known to break down on metallic surfaces: quoting John Tully, "Breakdown of the Born-Oppenheimer assumption is the rule rather than the exception in electron transfer reactions, photochemistry, and reactions at metal surfaces."
  http://www.chem.yale.edu/~tully/research.html
- ✓ Also known to break down on aromatic rings in conjunction with quantum entanglement of protons on those rings (see Chatzidimitriou-Dreismann & Mayers, *Journal of Chemical Physics* 116 pp. 1511 - 2002). Quoting from their paper, "… our NCS results …indicate that the physical meaning of … Born-Oppenheimer [approximation] should be critically reconsidered … at least for chemical processes in the …femtosecond time scale … [we also] demonstrate that short-lived protonic quantum entanglement and decoherence are of much broader significance than realized thus far."
  http://adsabs.harvard.edu/abs/2002JChPh.116.1511C

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

Summary of key steps that occur in electroweak catalysis of neutrons

Five-step hard-radiation-free process occurs in 300 - 400 nanoseconds or less

1. Collectively oscillating, quantum mechanically entangled, many-body patches of hydrogen (protons or deuterons) form spontaneously on metallic surfaces
2. Born-Oppenheimer approximation spontaneously breaks down, allows E-M coupling between local surface plasmon electrons and patch protons; enables application of input energy to create nuclear-strength local electric fields > 2 x 10^{11} V/m - increases effective masses of surface plasmon electrons in site
3. Heavy-mass surface plasmon electrons formed in many-body active sites can react directly with electromagnetically interacting protons; process creates neutrons and benign neutrinos via a collective electroweak $e + p$ reaction
4. Neutrons collectively created in sites have ultra-low kinetic energies; almost all absorbed by nearby atoms - few neutrons escape into environment; locally produced or ambient gammas converted directly into infrared photons by unreacted heavy electrons (US# 7,893,414 B2) - no deadly gamma emissions
5. Transmutation of atoms of locally present elements is induced at active sites

W-L explains temporal details of electroweak catalysis

Neutron production/capture occur on time-scales 10^{-22} to 10^{-12} seconds

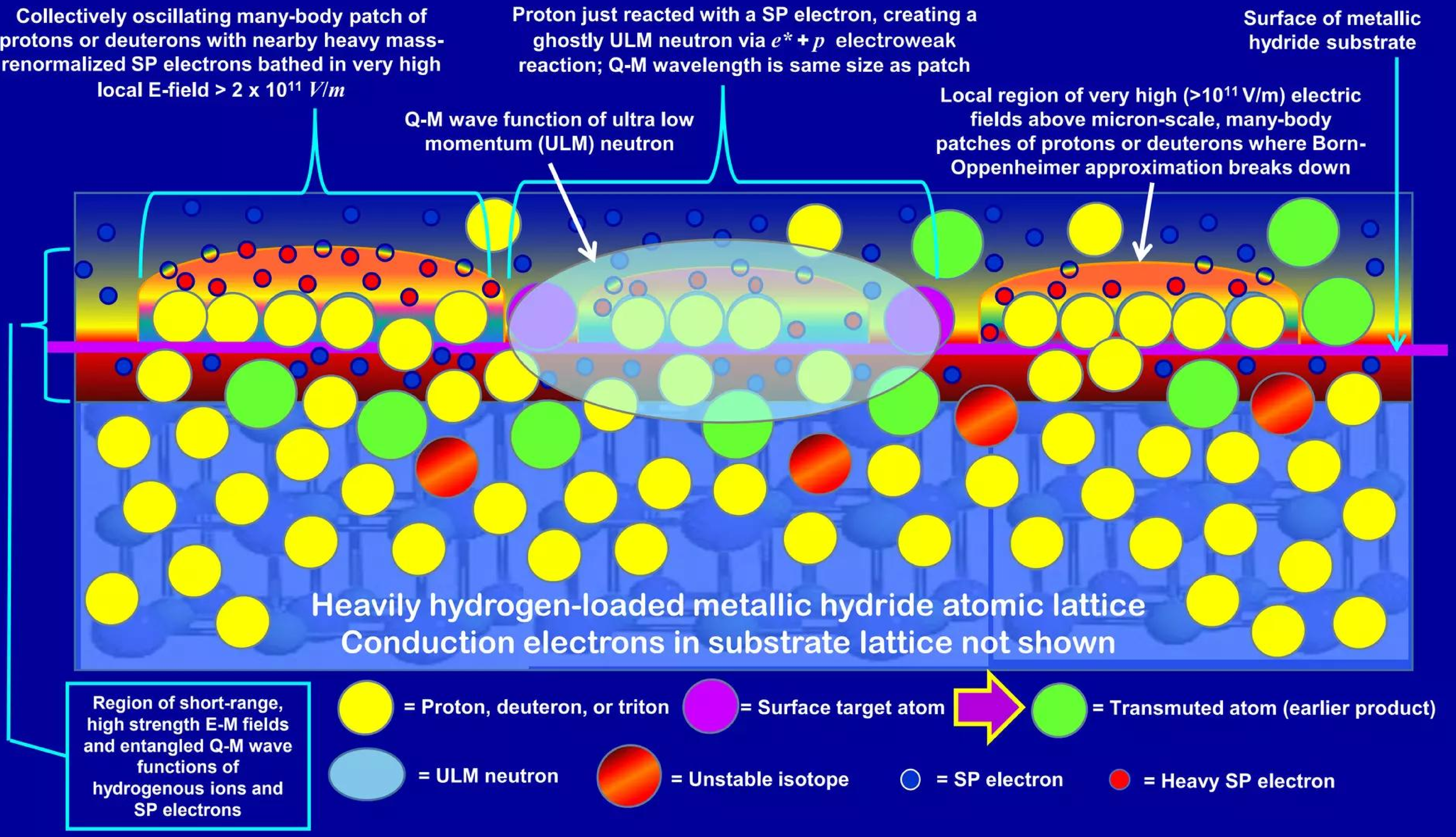
Fast chemical reactions take nanoseconds (10^{-9} s); 1 nanosec = 10^{9} attoseconds

- ✓ Ultracold neutron production can begin in an LENR many-body active sites sometime after local electric field strength exceeds ~ 2 x 10^{11} V/m (i.e., e^{-*} mass renormalization ratio β now greater than the minimum threshold ratio β_0) and an adequate number of mass-renormalized e^{-*} electrons have been created (enabled by local breakdown of the Born-Oppenheimer approximation in ~temporal conjunction with nonequilibrium energy inputs to active sites)
- ✓ Electroweak $e^{-*} + p^+$ or $e^{-*} + d^+$ reactions will occur during many-body, collectively oscillating protons' brief moments of quantum coherence (evanescent Q-M entanglement within patch); duration of such proton coherence times are on the order of attoseconds (~10^{-18} sec); these times have been measured by Chatzidimitriou-Dreismann (2005) and are cited on Slide #44 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewpahs-and-lenrsnov-25-2009
- ✓ Once e^{-*} mass renormalization set-up process has completed and heavy e^{-*} electrons and p^+ protons are ready to react (i.e., β now > β_0), electroweak reactions that follow will then only require ~10^{-19} to 10^{-22} sec to finish. Thus, while proton Q-M coherence times may be quite short, collective electroweak reactions that produce neutrons operate on even faster nuclear time-scales, thereby allowing collective neutron production to proceed at substantial rates
- ✓ Since collectively produced neutrons are ultra-ultra-low energy and local neutron capture processes occur on time-scales of picoseconds (10^{-12} sec), not nearly enough time for them to thermalize (that requires 0.1 - 0.2 μsec per S. Lamoreaux), so the vast majority of neutrons are captured locally on nearby atoms; systems do not emit any MeV-energy neutron radiation

Overview of microscopic LENR active sites on surface

Conceptual overview of 5-step electroweak catalysis and transmutation

Physical size of many-body active sites can range from 2 nm up to 100^+ microns



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

Proton just reacted with a SP electron, creating a ghostly ULM neutron via $e^* + p$ electroweak reaction; Q-M wavelength is same size as patch

Surface of metallic hydride substrate

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

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

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

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

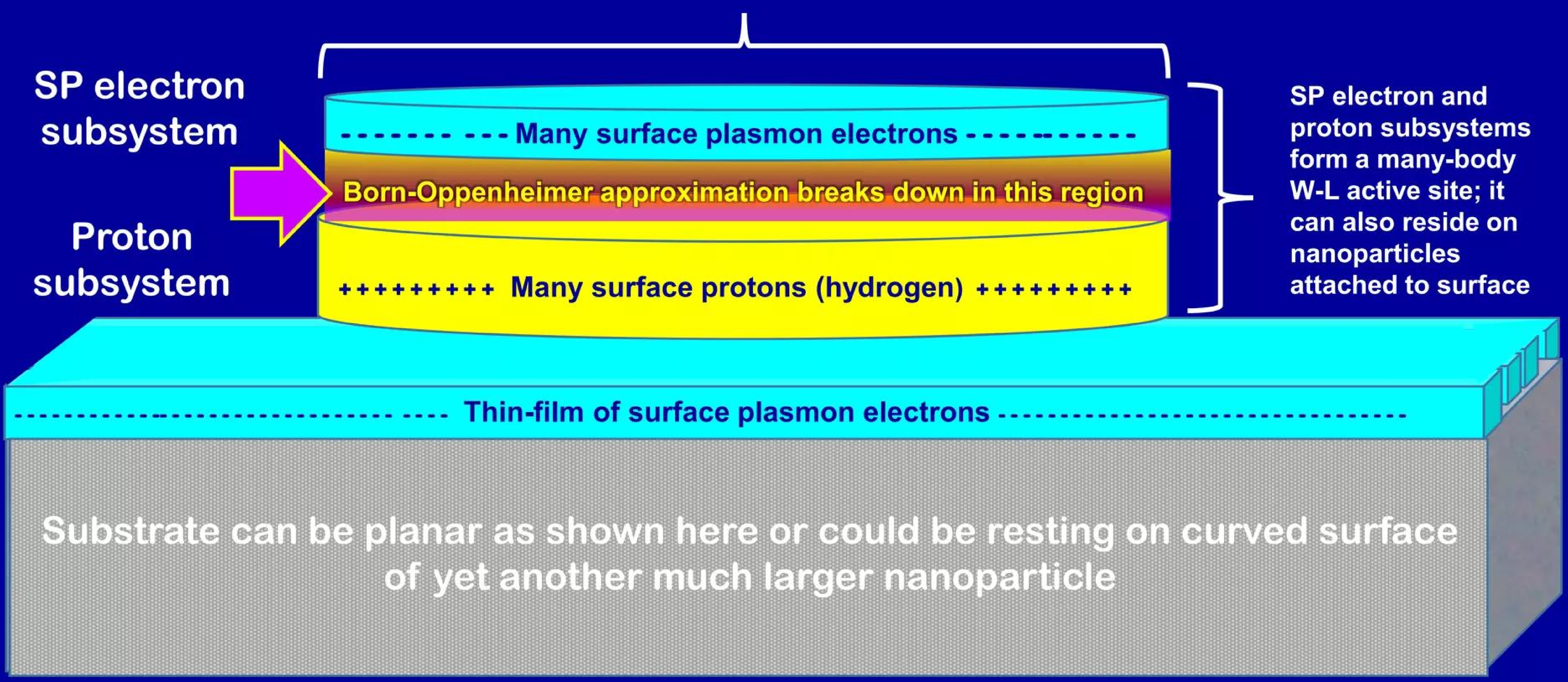
● = Proton, deuteron, or triton
● = Surface target atom ➡ ● = Transmuted atom (earlier product)
● = ULM neutron
● = Unstable isotope
● = SP electron
● = Heavy SP electron

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

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

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

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



Single nascent LENR-active site

SP electron subsystem

Proton subsystem

- - - - - - - - - - Many surface plasmon electrons - - - - - - - - - - -

Born-Oppenheimer approximation breaks down in this region

+++++++++ Many surface protons (hydrogen) +++++++++

SP electron and proton subsystems form a many-body W-L active site; it can also reside on nanoparticles attached to surface

- Thin-film of surface plasmon electrons -

Substrate can be planar as shown here or could be resting on curved surface of yet another much larger nanoparticle

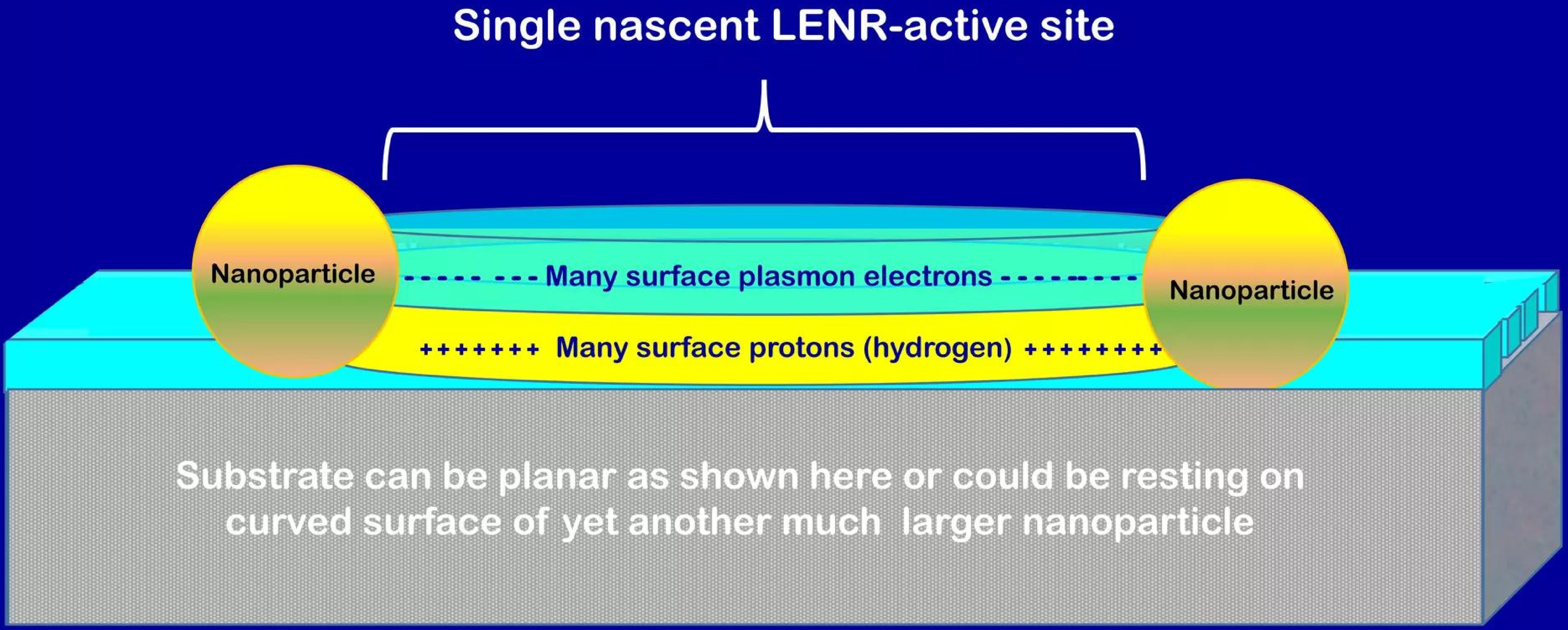
Input energy creates high electric fields in LENR active sites

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

Huge electric field increase effective masses of some patch SP electrons

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

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



LENRs occur in microscopic active sites found on surfaces

Many-body collections of protons and electrons form spontaneously

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

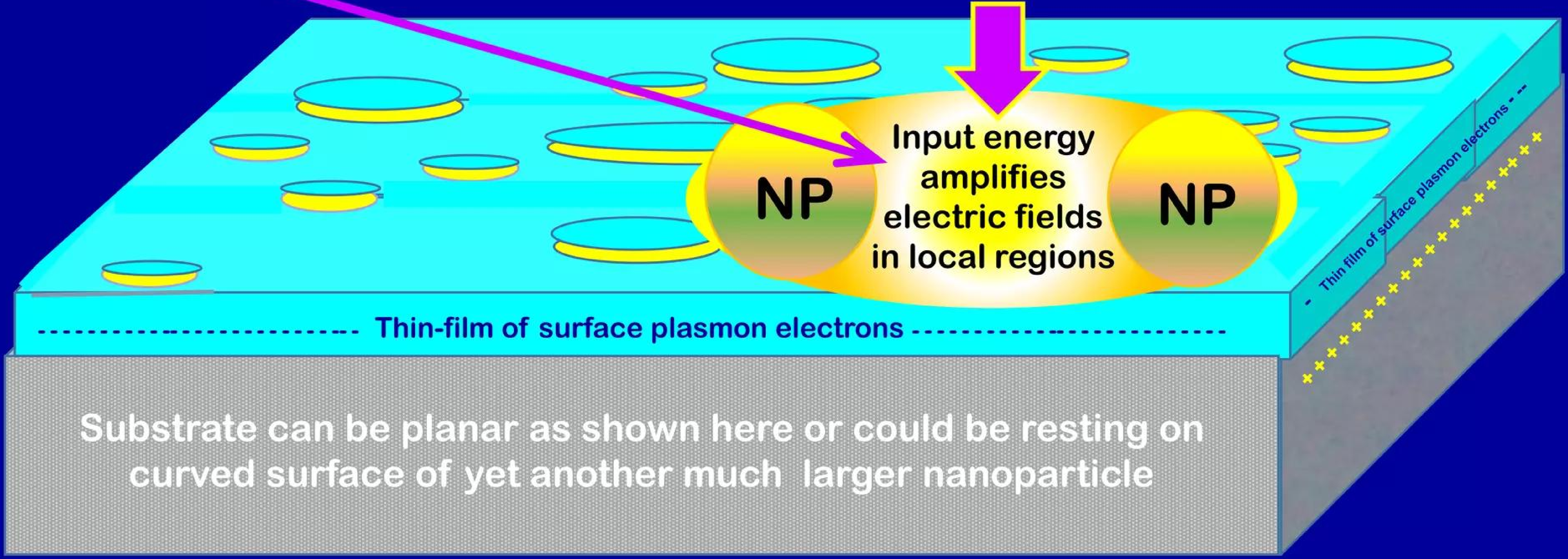
Intense heating in LENR-active sites will form μ-scale event craters on substrate surfaces

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

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

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

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



Substrate can be planar as shown here or could be resting on curved surface of yet another much larger nanoparticle

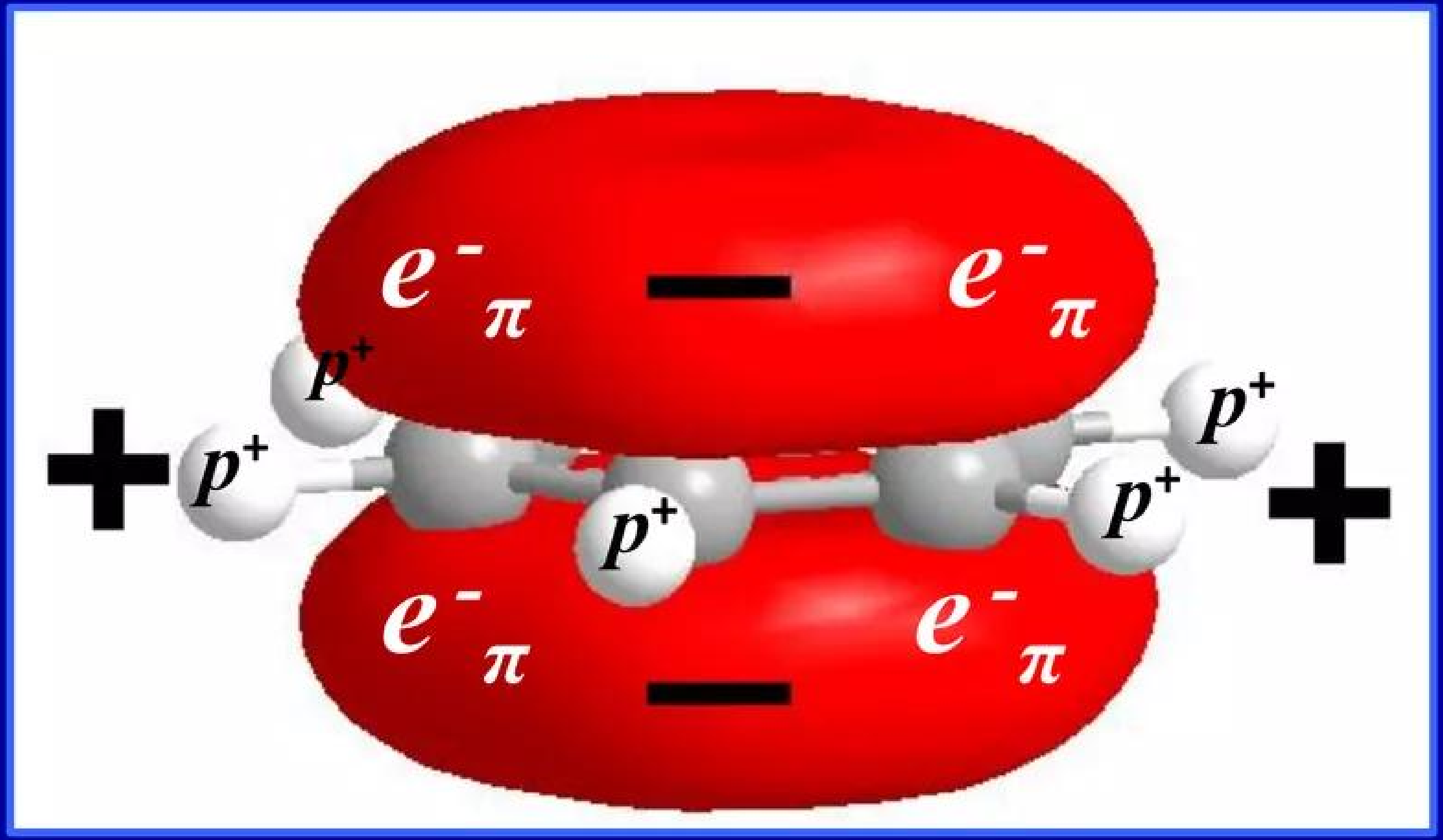
Lattice extended Widom-Larsen theory to aromatic rings

Benzene ring is 2 nm molecular analogue of LENR active site on metal

Protons (Hydrogen) on aromatic ring and related π electrons are Q-M entangled

Lattice's conjecture that electrons on aromatic rings can behave like the functional equivalents of surface plasmons on metals was eventually confirmed by A. Manjavacas *et al*. (2013)

Red indicates π many-electron clouds on both sides of Carbon aromatic ring



Only tiny fraction of total number of π electrons are shown in this graphic

Synopsis: back in 2009, Lattice predicted that under proper conditions, electromagnetic energy can be transferred into hydrogenated aromatic rings such that ultra low momentum neutrons are created from ring hydrogens (protons) via LENR catalysis of an electroweak $e_\pi + p \rightarrow n + v_e$ reaction; neutrons then tend to capture on nearby ring Carbon atoms, inducing a nuclear transmutation process

"Technical Overview - PAHs and LENRs"
L. Larsen, Lattice Energy LLC
November 25, 2009 (see slides #42 - 45)

http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewpahs-and-lenrsnov-25-2009

Lattice extended Widom-Larsen theory to aromatic rings

Collective electroweak catalysis of neutrons on molecular LENR active site

- ✓ Delocalized clouds of π electrons situated above and below 6-Carbon aromatic ring structures are in very close physical proximity to protons (hydrogen atoms), oscillate collectively, and are mutually Q-M entangled (Manjavacas *et al.* - 2013)
- ✓ Protons that are also attached to an aromatic ring's Carbon atoms oscillate collectively and are Q-M entangled with each other (this was first observed and reported by Chatzidimitriou-Dreismann - 2005)
- ✓ Local breakdown of Born-Oppenheimer approximation occurs on aromatic ring structures; this enables E-M coupling and energy transfers between collectively oscillating π electrons and nearby protons (H) on aromatic ring; during E-M energy input, very high fluctuating local electric fields are created in vicinity of the ring
- ✓ When an aromatic structure is adsorbed onto the surface of a metallic substrate, it will spontaneously orient itself as it approaches so that the ~flat ring plane of an aromatic molecule ends-up ~parallel to the substrate surface. Born-Oppenheimer approximation also breaks down there, enabling further E-M coupling and energy transfers between Carbon-ring π electrons and thin-film 'sea' of surface plasmon electrons covering a substrate's surface (S. Jenkins, *Proc. Royal Soc.* 465 - 2009)
- ✓ Dynamics are analogous to manner in which LENR active sites operate on loaded metallic hydride surfaces. Molecular aromatic ring structure becomes functional analogue of a many-body LENR active site in which neutrons can be produced collectively via electroweak $e + p$ reaction; neutrons will tend to capture on nearby ring Carbons --- this also applies to multi-ring polycyclic aromatic hydrocarbons

Further technical reading

“Index” provides comprehensive guide to hyperlinked information

“Index to key concepts and documents”
v. #20 updated and revised through Jan. 8, 2015
L. Larsen, Lattice Energy LLC, May 28, 2013
http://www.slideshare.net/lewisglarsen/lattice-energy-llc-index-to-documents-re-widomlarsen-theory-of-lenrsmay-28-2013

“Surprising similarities between LENR-active sites and enzymatic catalysis”
L. Larsen, Lattice Energy LLC, March 20, 2015
http://www.slideshare.net/lewisglarsen/lattice-energy-llc-surprising-similarities-between-lenr-active-sites-and-enzymatic-catalysis-march-20-2015

“Beyond the Haber-Bosch process for ammonia production:
fixing Nitrogen at near-ambient temperatures and pressures”
L. Larsen, Lattice Energy LLC, April 30, 2015
http://www.slideshare.net/lewisglarsen/lattice-energy-llc-beyond-the-haberbosch-process-for-ammonia-production-april-30-2015

“Scalability of LENR power generation systems”
L. Larsen, Lattice Energy LLC, November 29, 2015
http://www.slideshare.net/lewisglarsen/lattice-energy-llc-scalability-of-lenr-power-generation-systems-nov-29-2015