Lattice Energy LLC

Liu et al. published new paper in *Nature Communications*

Reported detectible increase in effective mass of electrons in $ZrTe_5$ with application of extremely high magnetic field

Liu et al.'s $ZrTe_5$ experimental system operates similarly to the Widom-Larsen theory of ultra low momentum neutron reactions (LENRs) in condensed matter wherein many-body collective effects create heavy e^* surface plasmon electrons having significant multiples of their rest mass

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

Heavy e^* electrons + protons → neutrons + neutrinos (benign photons, fly into space)

Lewis Larsen
President and CEO

August 30, 2016

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

Liu et al. increase electron mass with applied magnetic field

Prior to first publication of the Widom-Larsen theory of LENRs (2005), very substantial increases in effective masses of electrons which could then engage in direct electroweak reactions with protons was thought impossible in condensed matter at moderate temperatures.

In their *Nature Communications* paper, Liu et al. used a ~ 2-D $ZrTe_5$ system. In their experiments, they measured magnetoresistance and were able to detect real increases in effective mass of electrons exposed to an extremely high applied magnetic field while at low temperatures. In this system, input energy required to create heavier-mass electrons came directly from the applied magnetic field.

Liu et al.'s detection of upward shifts in electron mass appears to be an experimental first. Conceptually, their $ZrTe_5$ system functions very much like a magnetic analog of ~2-D LENR active sites on substrate surfaces. In such LENR sites, effective masses of surface plasmon electrons increase when they are exposed to nuclear-strength local electric fields above 2.5×10^{11} V/m for periods of nanoseconds.

Increased electron masses crucial in Widom-Larsen LENRs

Protons react directly with heavy-mass electrons to make neutrons

Input energy source boosts local E-fields and drives neutron production

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

Heavy e^* electrons + protons → neutrons + neutrinos (benign photons, fly into space)

Conceptually, Liu *et al.*'s experimental system is akin to a magnetic variant of the Widom-Larsen theory of ultra low momentum neutron reactions (LENRs) in condensed matter; major difference is that their $ZrTe_5$ system does not produce neutrons via an electroweak reaction. In LENRs, many-body collective quantum effects and extremely high nuclear-strength local electric fields > 2 x 10^{11} V/m occur in micron-scale active sites comprised of Q-M entangled, collectively oscillating surface plasmon electrons and protons. In $ZrTe_5$, measured increases in effective electron mass were relatively small, max. $m^*/m_e = 0.26$. In LENRs, extremely high localized *electric* fields increase effective masses of exposed SP electrons to high-enough multiples of their initial rest mass such that direct electroweak reactions between electrons and protons are allowed. In Widom-Larsen theory, the *minimum* increase in effective mass required to produce ultra low momentum neutrons and electron neutrinos is $m^*/m_e > 2.531$.

AMBER (Advanced Materials and BioEngineering Research)

Amber Centre press release published on *ScienceDaily* August 29, 2016

ScienceDaily
Your source for the latest research news

AMBER CRANN Trinity College Dublin The University of Dublin RCSI UCC

https://www.sciencedaily.com/releases/2016/08/160829111117.htm

"Electrons with no mass acquire a mass in the presence of a high magnetic field"

"An international team of researchers has for the first time discovered that in a very high magnetic field an electron with no mass can acquire a mass. Understanding why elementary particles -- e.g. electrons, photons, neutrinos -- have a mass is a fundamental question in physics and an area of intense debate."

"Prof. Stefano Sanvito, Principal Investigator at … AMBER … centre … and the CRANN Institute and Professor in Trinity's School of Physics said, 'This is a very exciting breakthrough because until now, nobody has ever discovered an object whose mass can be switched on or off by applying an external stimulus … We have demonstrated for the first time one way in which mass can be generated in a material. In principle the external stimulus that enabled this, the magnetic field, could be replaced with some other stimulus … when a magnetic field of 60 Tesla is applied (a million times more intense than the earth's magnetic field) the current is drastically reduced and the electrons acquire a mass. An intense magnetic field in $ZrTe_5$ transforms slim and fast electrons into fat and slow ones'."

Liu et al. paper just published in *Nature Communications*

Applied very high magnetic field increases the effective electron masses

nature COMMUNICATIONS

http://www.nature.com/articles/ncomms12516

"Zeeman splitting and dynamical mass generation in Dirac semimetal $ZrTe_5$"
Y. Liu et al., *Nature Communications* article number: 12516 (August 12, 2016)

Abstract: "Dirac semimetals have attracted extensive attentions in recent years. It has been theoretically suggested that many-body interactions may drive exotic phase transitions, spontaneously generating a Dirac mass for the nominally massless Dirac electrons. So far, signature of interaction-driven transition has been lacking. In this work, we report high-magnetic-field transport measurements of the Dirac semimetal candidate $ZrTe_5$. Owing to the large *g* factor in $ZrTe_5$, the Zeeman splitting can be observed at magnetic field as low as 3 T. Most prominently, high pulsed magnetic field up to 60 T drives the system into the ultra-quantum limit, where we observe abrupt changes in the magnetoresistance, indicating field-induced phase transitions. This is interpreted as an interaction-induced spontaneous mass generation of the Dirac fermions, which bears resemblance to the dynamical mass generation of nucleons in high-energy physics. Our work establishes Dirac semimetals as ideal platforms for investigating emerging correlation effects in topological matters."

Electroweak e + p reaction is key in Widom-Larsen theory

Protons react directly with increased-mass electrons to make neutrons

Need input energy source such as electricity to drive LENR neutron production

Heavy-mass e^* electrons + protons → neutrons + neutrinos (benign photons, fly into space)

Require source(s) of input energy

Input energy creates electric fields > 2.5 x10[11] V/m

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

Many-body collective electroweak neutron production

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

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

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

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

Radiation-free LENR transmutation

Neutrons + capture targets → heavier elements + decay products

Neutrons induce nuclear transmutations that release enormous amounts of clean, CO_2-free heat

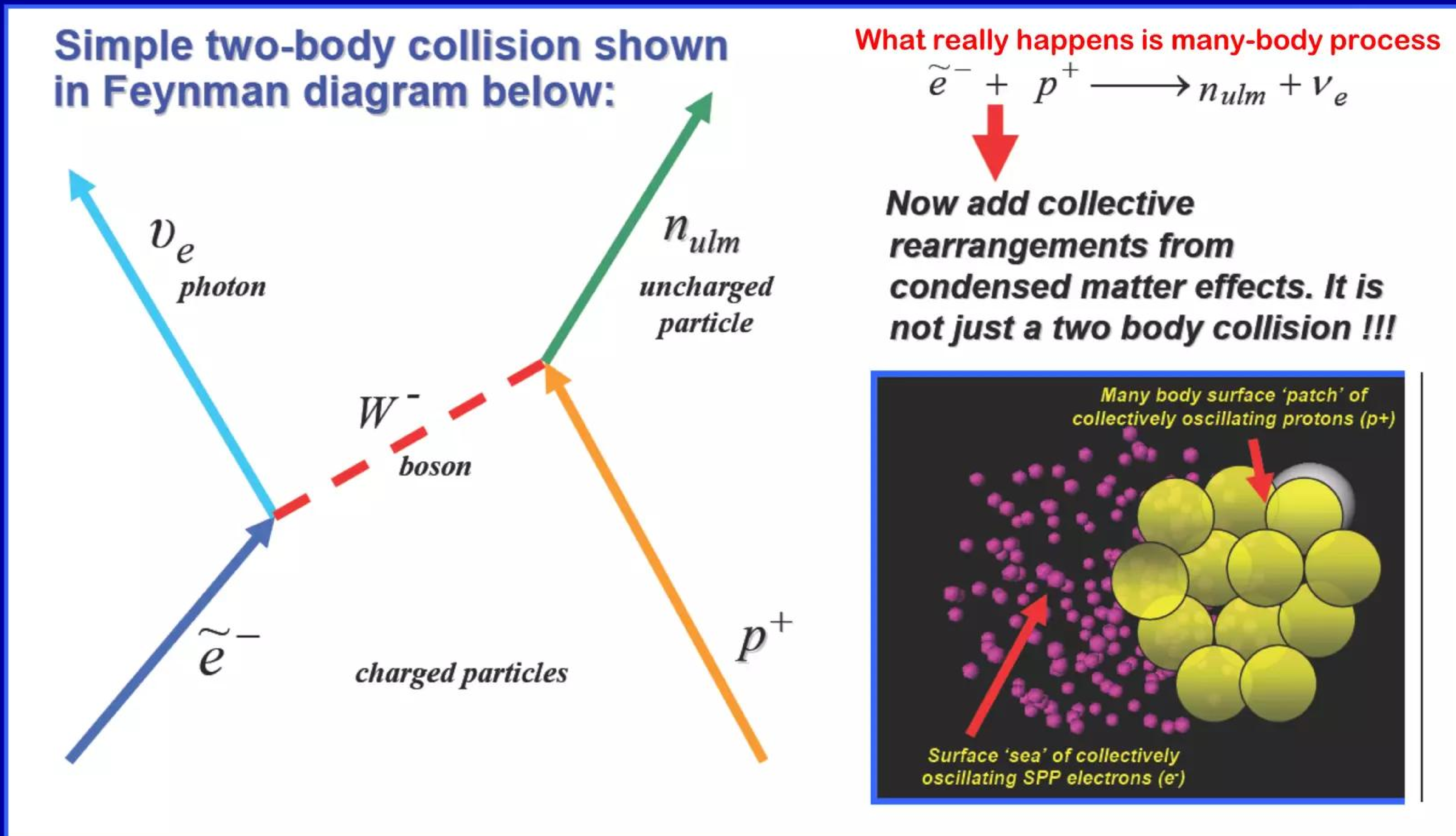
Many-body collective and quantum effects crucial to LENRs

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

Many-body collective effects involve mutual quantum entanglement

What really happens is a many-body reaction amongst entangled particles

This collective electroweak reaction can thus be written as: $e_n + p_n \rightarrow n_{ulm} + \nu_e$



Appropriate input energy is required produce LENR 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):

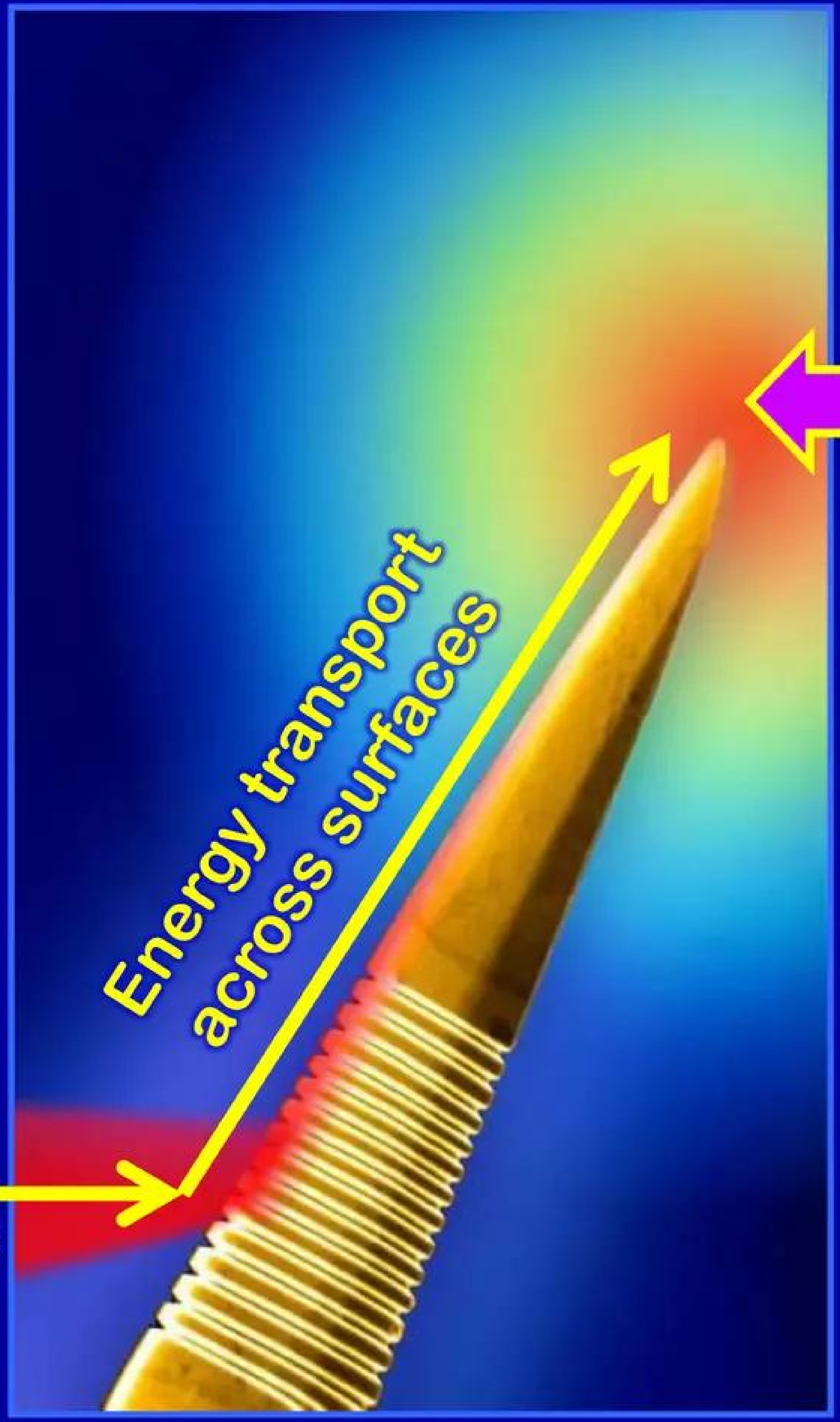
- ✓ **Electrical currents** - i.e., an electron 'beam' of one sort or another can serve as a source of input energy for producing neutrons via $e + p$ electroweak reaction
- ✓ **Ion currents** - passing across a surface or an interface where SP electrons reside (i.e., an ion beam that can be comprised 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

Surface plasmons can mediate input energy to LENR sites

SP electrons can absorb, transport, concentrate, and store input energy

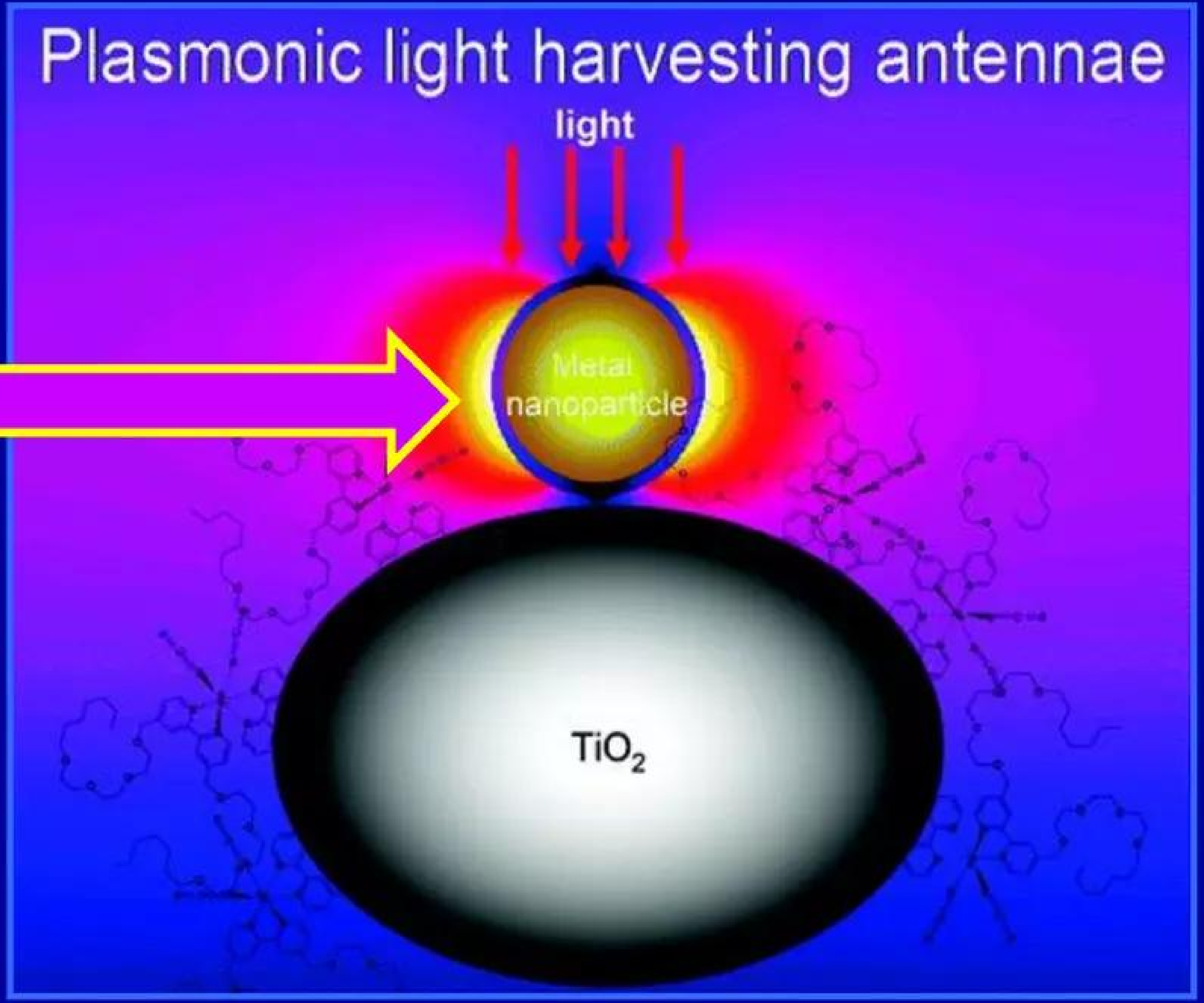
Properly engineered LENR target fuel nanoparticles can capture E-M input energy

Sharp tips can exhibit "lightning rod effect" with very large increases in local electric fields



Regions of very high E-M fields

Source of image just below is the Wiesner Group at Cornell University; shows target nanoparticle on TiO_2



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

See: "Plasmonic dye-sensitized solar cells using core-shell metal-insulator nanoparticles," M. Brown *et al.*, *Nano Letters* 11 (2) pp. 438 - 445 (2011)

http://pubs.acs.org/doi/abs/10.1021/nl1031106

Many-body collective quantum effects are crucial to LENRs

LENRs occur in microscopic active sites on suitable substrate surfaces

Collective many-body transport and concentration of incident E-M energy in sites

- ✓ Under proper conditions, the $e + p \rightarrow n + \nu_e$ (endothermic by 0.78 MeV) electroweak "neutronization" reaction (surface plasmon SP electrons react directly with surface protons to make a neutron and an electron neutrino) can occur at surprisingly high rates. Reactions occur in micron-scale (range in size from ~2 nm to ~100 microns), monolayer, many-body ~2-D patches of entangled, collectively oscillating protons or deuterons that, for example, form spontaneously on fully-loaded metallic hydride surfaces (this happens when the bulk hydride interstitial sites for Hydrogen as p^+ are all occupied)
- ✓ These nascent surface patch sites can become LENR-active when sufficient amounts of E-M input energy in proper form is transported to, and then concentrated in, them by wide-area film of entangled SP electrons. Term $(\beta - \beta_0)^2$ in our published rate equation reflects the degree to which heavy-mass (renormalized) e^{-*} electrons in a given active site exceed the minimum threshold ratio for neutron production β_0. Details are explained in our first principles rates calculation preprint (arXiv, 2007). All other things being equal, the higher the density of $e^{-*}p^+$ reactants and the greater the rate and quantity of appropriate forms of nonequilbirum energy inputs, the higher the rate of ULE neutron production in nm- to μm-scale LENR active sites

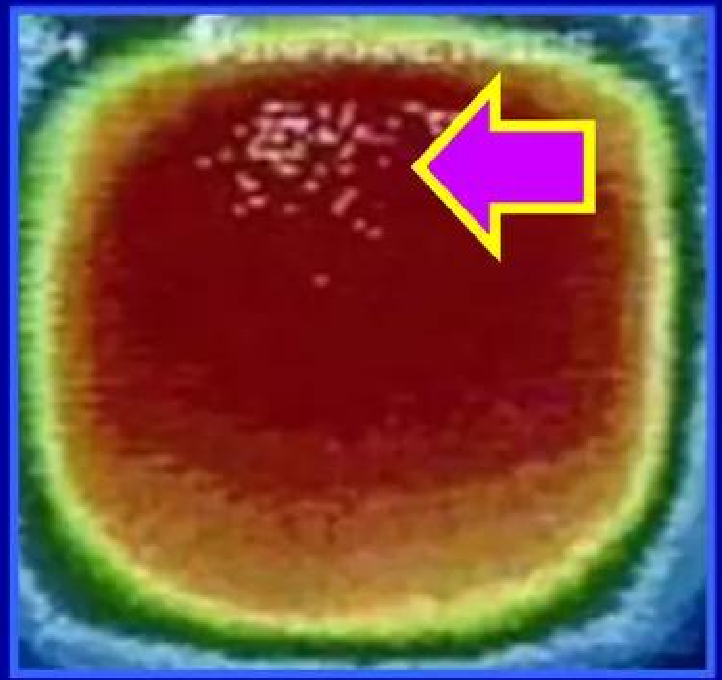
Widom-Larsen provides description for LENR active sites

Size of these active sites ranges from 2 nanometers up to ~100⁺ microns

Active sites have limited lifetimes before being destroyed by fast nuclear heating

- ✓ Per Widom-Larsen theory LENRs occur in localized micron-scale LENR active sites on ~planar surfaces: at certain types of interfaces; or curved surfaces of various shaped nanoparticles
- ✓ Tiny LENR active sites live for less than ~300 - 400 nanoseconds before being destroyed by intense heat; local peak temps range from 4,000 - 6,000° C; LENR active sites spontaneously reform under right conditions in well-engineered LENR thermal devices
- ✓ Microscopic 100-micron LENR hotspot can release as much as several Watts of heat in < 400 nanoseconds; create crater-like features on surfaces that are visible in SEM images and show evidence for flash-boiling of both precious & refractory metals
- ✓ Extensions to W-L theory's physics have been integrated with unpublished details of Lattice's conceptual model for LENR active sites. This company proprietary knowledge allows vastly better selection of nanostructural materials, channeling of very complex LENR transmutation networks, and choice of best fuel target elements. Also enables computer-aided design and very realistic simulation of fabricated nanostructures optimized for rapid formation and predictable operation of LENR active sites

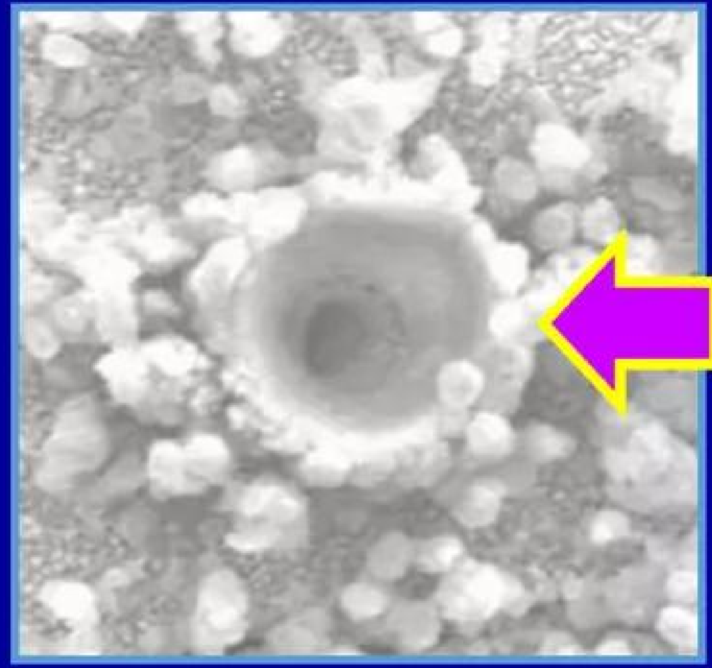
LENR hotspots on Pd cathode
Infrared video of LENR hotspots



Credit: P. Boss, U.S. Navy

http://www.youtube.com/watch?v=OUVmOQXBS68

100 μ LENR crater in Pd cathode
LENR electrochemical cell



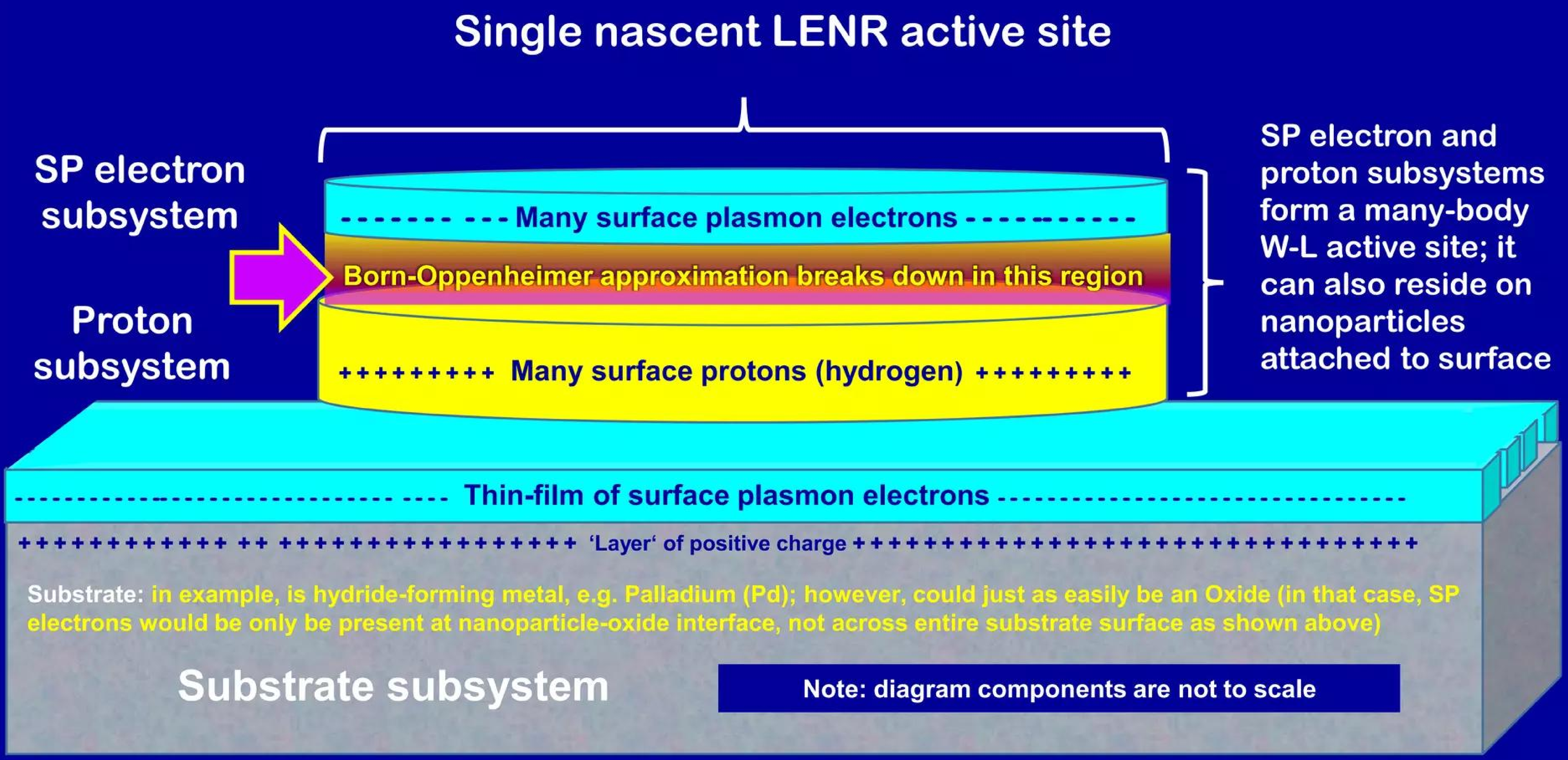
Credit: P. Boss, U.S. Navy

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



Input energy creates high electric fields in LENR active sites

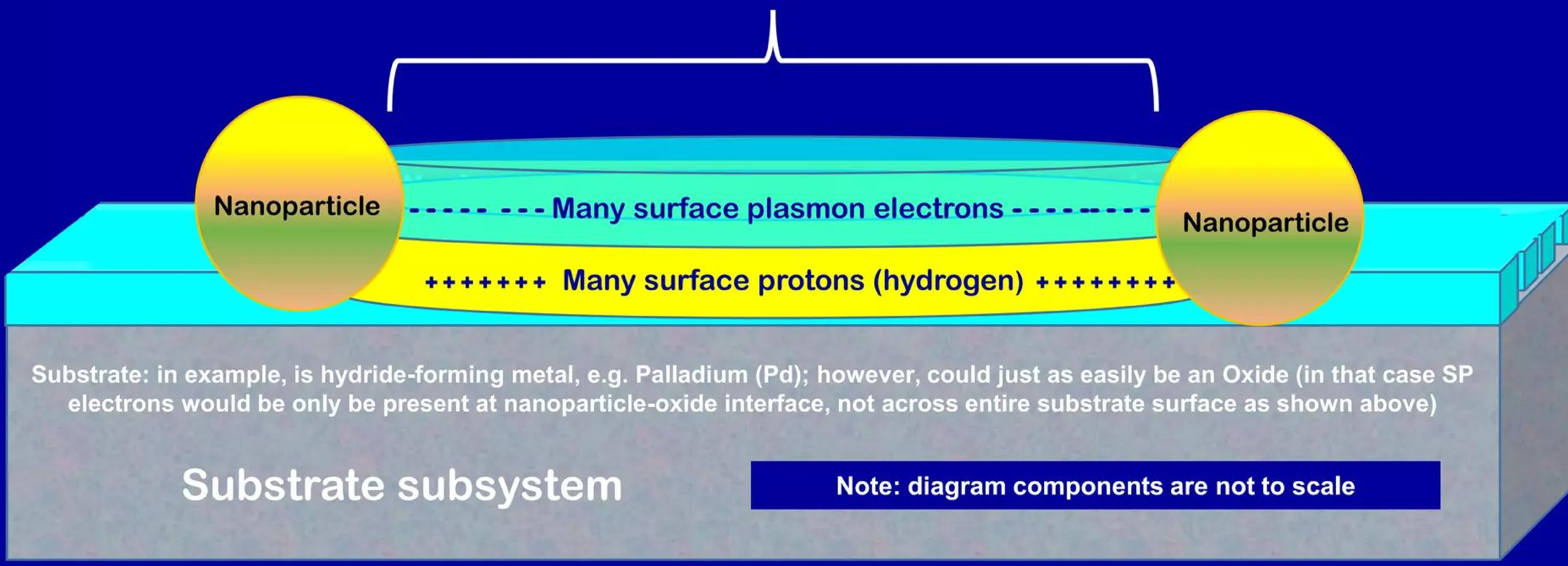
Born-Oppenheimer breakdown enables nuclear-strength local E-field

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]

Single nascent LENR active site



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

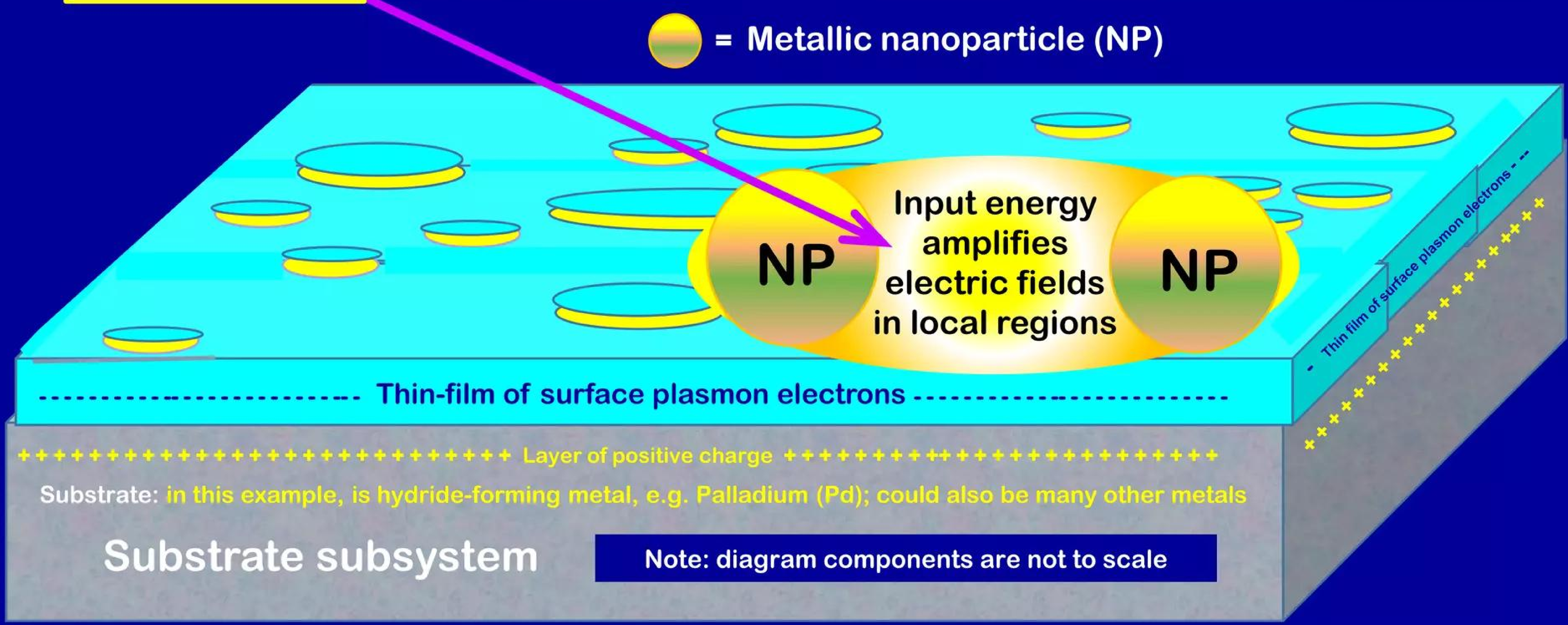
After being produced, neutrons capture on targets in/around active sites

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

n + (Z, A) → (Z, A+1) [neutrons capture on nearby target atoms]

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

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

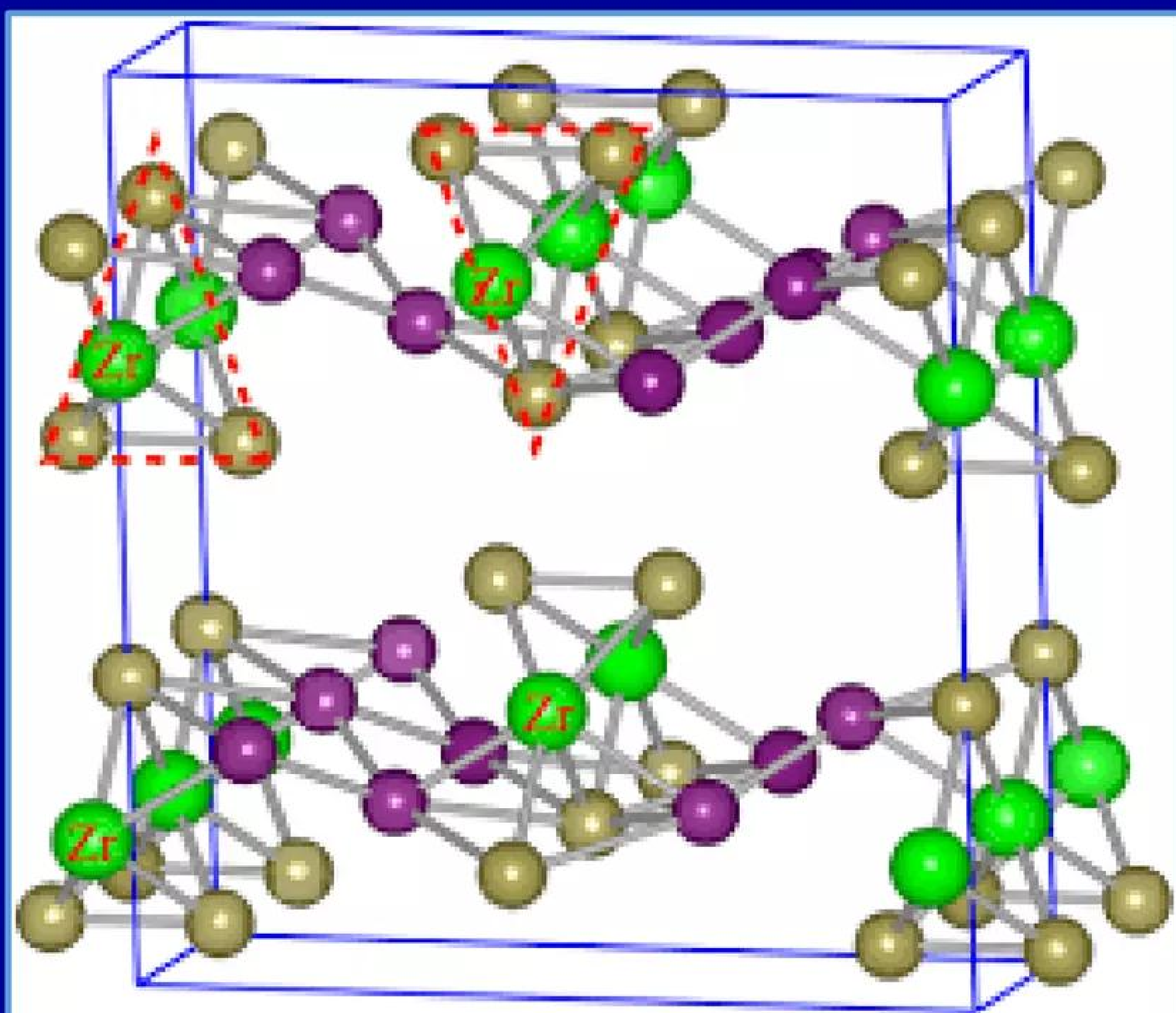


$ZrTe_5$: quasi-2D atomic structure with charge-neutral layers

LENR active sites composed of entangled protons & electrons also ~ 2D

Applied E-M fields increase masses of electrons in 2-D $ZrTe_5$ and $[e^-_n \, p^+_n]$ systems

Fig. 1 in H. Weng et al. (2014)



"$ZrTe_5$ shows strong quasi-2D anisotropy. The prismatic and the zigzag chains are connected through the apical Te atoms, and the Te-Te bond length between two chains is about 0.4 Å longer than that in the zigzag chain. If the Zr and Te_d dimer atoms are neglected, the remaining apical Te_a and zigzag Te_z atoms can be viewed as a waved grid of Te square-lattice sheet leading to a stable quasi-2D structure. Each $ZrTe_5$ layer is nominally charge neutral, and the interlayer distance (along the b axis) is quite large (about 7.25 Å), suggesting the weak interlayer coupling, presumably of van der Waals type."

Fig. 1 (a) in "Transition-metal pentatelluride $ZrTe_5$ and $HfTe_5$: a paradigm for large-gap quantum spin Hall insulators" H. Weng *et al*. *Physical Review X* 4 pp. 011002 1-8 (2014)

Application of pressure induces superconductivity in $ZrTe_5$

5/6/2016: "Researchers discover superconductivity in pressurized $ZrTe_5$"

$ZrTe_5$ is superconductor at low temperatures with pressures > 5 GPa (~50,000 atm)

http://english.cas.cn/newsroom/research_news/201605/t20160506_162813.shtml

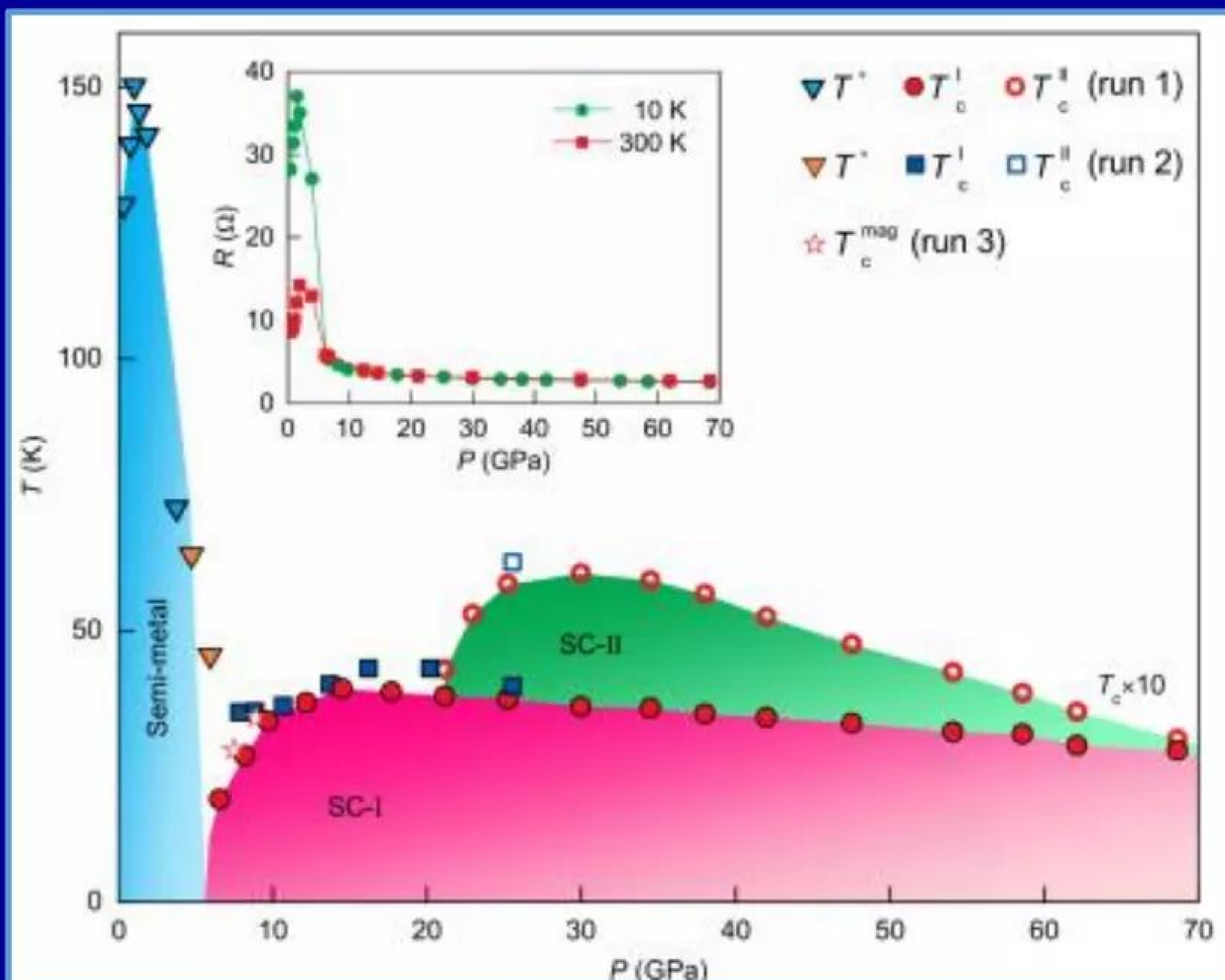


Figure 1. Temperature-pressure phase diagram of $ZrTe_5$ single crystal
Image by ZHOU Yonghui
http://www.pnas.org/content/113/11/2904

"As a new type of topological materials, $ZrTe_5$ shows many exotic properties under extreme conditions. Utilizing resistance and *ac* magnetic susceptibility measurements under high pressure, researchers found while the resistance anomaly near 128 K is completely suppressed at 6.2 GPa, a fully superconducting transition emerges. The superconducting transition temperature T_c increases with applied pressure, and reaches a maximum of 4.0 K at 14.6 GPa, followed by a slight drop but remaining almost constant value up to 68.5 GPa. At pressures above 21.2 GPa, a second superconducting phase with the maximum T_c of about 6.0 K appears and coexists with the original one to the maximum pressure studied in this work."

Do LENR [$e^-_n\ p^+_n$] sites exhibit fleeting superconductivity?

Energy input to 2-D $ZrTe_5$ and [$e^-_n\ p^+_n$] systems can boost electron mass

Data suggests possibility superconductivity may occur in many-body [$e^-_n\ p^+_n$] sites

- ✓ In May - Sept. 2005, while elaborating Widom-Larsen theory of LENRs to explain characteristic suppression of high-energy gamma radiation that has been routinely observed in LENR experimentation for over 20 years, Allan Widom and I noticed intriguing theoretical possibility that anomalously high surface electrical conductivity might occur in vicinity of many-body patches of entangled, collectively oscillating protons (or deuterons, tritons) at local electric field strength values close to thresholds required for collective electroweak neutron production. Not wishing to unnecessarily clutter an otherwise relatively concise paper by introducing additional tangentially related theory issues, we merely remarked on pp. 2 that "... added heavy electrons produce an anomalously high surface conductivity at the LENR threshold."
- ✓ In Nov. - Dec. 2005, Andrei Lipson (Russian Academy of Sciences, Moscow) presented experimental results at an ICCF-12 conference in Yokohama, Japan, concerning what appeared to be high temperature superconductivity occurring in a subset of small regions in Hydrogen-cycled 12.5 μm thick Pd/PdO foil
- ✓ While greatly doubted by some researchers, Tripodi *et al.'s* extremely controversial experimental measurements published in *Physica C* (2003 - 2004) have never been decisively refuted. He claimed his lab data indicated that exotic superconductivity apparently occurred at or above room temperature in tiny local regions of pure Palladium having high stoichiometric PdHx ratios (x > 1.0). Interestingly, Lipson *et al.'s* experimental data (2005) may support Tripodi *et al.'s* claims, at least in part

Speculation about HT superconductivity in $[e^-_n p^+_n]$ sites

"Absorption of nuclear gamma radiation by heavy electrons on metallic hydride surfaces" Widom & Larsen arXiv preprint (2005)

- ✓ Quoting excerpts from our 2005 arXiv preprint: "In order to achieve heavy electron pair energies of several MeV … The energy differences between electron states in the heavy electron conduction states is sufficient to pick up the 'particle-hole' energies of the order of MeV. Such particle-hole pair production in conduction states of metals is in conventional condensed matter physics described by electrical conductivity … energy spread of heavy electron-hole pair excitations implies that a high conductivity near the surface can persist well into the MeV photon energy range, strongly absorbing prompt gamma radiation … energy spread of the excited particle hole pair will have a cutoff of about 10 MeV based on mass renormalization of … the electron."
- ✓ While no direct experimental measurements of energy spreads in many-body LENR $[e^-_n p^+_n]$ patches have ever been made, one could speculate that they might be much larger than those found in presently well-known Types 1 and 2 superconductors. If 'mirror' Cooper pairs of SP electrons and protons are able to form in coherent $[e^-_n p^+_n]$ patches, then perhaps it is not totally unreasonable to expect that pairing energies therein might exceed value of 150 meV Mourachkine (2004) calculated for a RTSC at 580 ºK

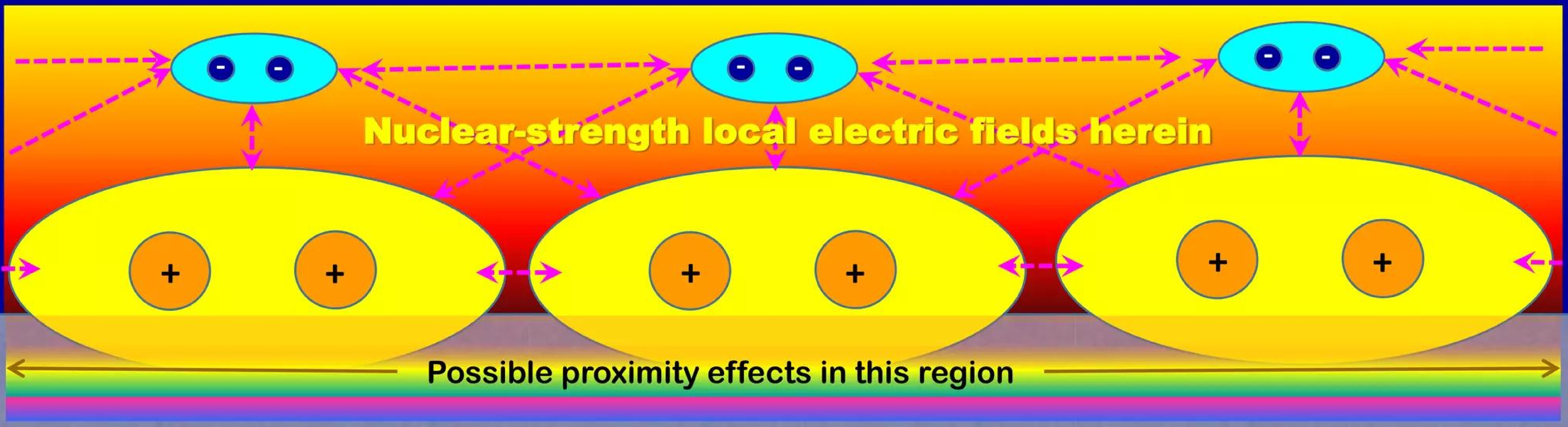
Speculation: quantum condensates in 2-D LENR [$e^-_n\, p^+_n$] sites

Can entities like Cooper pairs form with entangled protons and electrons?

What might be facilitating the formation of Cooper pairs in such 2-D condensates?

"Novel attractive force between ions in quantum plasmas"
P. Shukla and B. Eliasson
Physical Review Letters 108 pp. 165007 - 165012 (2012)

http://arxiv.org/pdf/1112.5556v7.pdf



Substrate: in this example, it is a hydride-forming metal, e.g. Palladium (Pd); however, it could just as easily be an Oxide (in that case, SP electrons would be present at interface between patches and substrate, not across the entire substrate surface as would be the case if the underlying substrate was a metal)

Speculation about HT superconductivity in [e^-_n p^+_n] sites

Intriguing technological opportunity if it ultimately turns-out to be correct

Superconducting devices could someday be built that are able to operate > 273 °K

- ✓ At the moment [e^-_n p^+_n] patches are evanescent and have short lifetimes because once they go nuclear and make neutrons, they effectively destroy themselves which locally wipes-out any HT superconductivity that might be present
- ✓ However, there could potentially be a technological workaround for this vexing problem: imagine designing and fabricating a superconducting device in which local nanoscale electric field strengths can be tightly controlled and persistently clamped at values that are maintained just a little below thresholds where neutrons are produced. For a concrete example, assume that our hypothetical device consists of a graphene ribbon decorated with specially engineered, conductive nanoparticles that can effectively clamp surface electric fields within key design specifications, thus enabling what is effectively a wire that can function as a current-carrying superconductor at temperatures up to 580 °K

"High-temperature superconductivity in patches"
Lattice Energy LLC, August 23, 2012 [92 slides]
http://www.slideshare.net/lewisglarsen/lattice-energy-llc-hightemperature-superconductivity-in-patchesaug-23-2012

"High-temperature superconductivity in patches - Addendum"
Lattice Energy LLC, September 11, 2012 [25 slides]
http://www.slideshare.net/lewisglarsen/lattice-energy-llchightemperature-superconductivity-in-patchesaddendumsep-11-2012

Publications about the Widom-Larsen theory of LENRs

Index provides comprehensive guide to available online information

"Ultra low momentum neutron catalyzed nuclear reactions on metallic hydride surfaces"
A. Widom and L. Larsen (author's copy)
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

"A primer for electro-weak induced low energy nuclear reactions"
Y. Srivastava, A. Widom, and L. Larsen (author's copy)
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

"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

"Index to key concepts and documents" all hyperlinks in document are 'live'
v. #21 updated and revised through Sept. 7, 2015
L. Larsen, Lattice Energy LLC, May 28, 2013 [133 slides] download is enabled
http://www.slideshare.net/lewisglarsen/lattice-energy-llc-hyperlinked-index-to-documents-re-widomlarsen-theory-and-lenrs-september-7-2015