Low Energy Nuclear Reactions in the Standard Model [Reazioni Nucleari in Modello Standard]

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Presented by YS
@ Coherence 2013/3

Auletta CIRPS Roma I: Martedi, Ottobre 15 2013

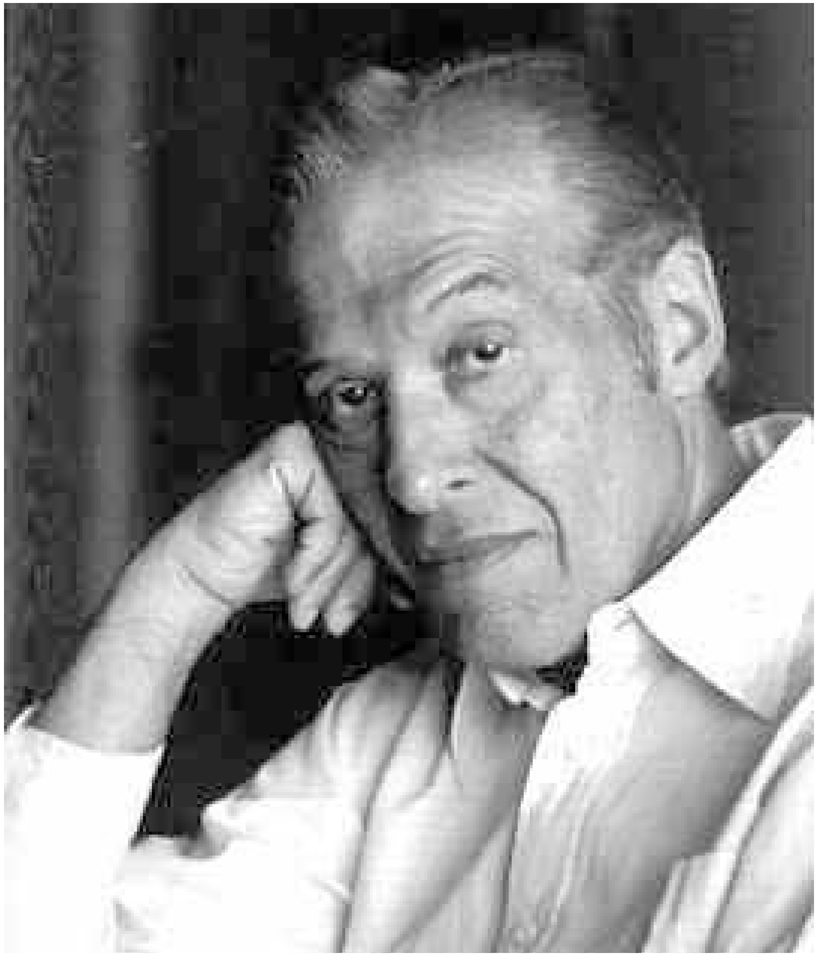
Il Piano dell’ seminario: Plan of the talk

- Un breve reassunto di teoria per innescare reazioni nucleari a bassa energia:

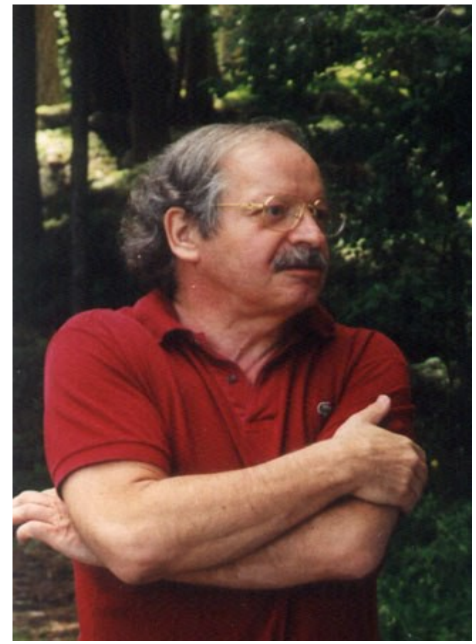
  [Brief review of Low Energy Nuclear Theory [LENT]]

- Applicazioni a tre materiali “Smart”: piro e piezo-elettrici, piezo-magnetici [Application to Pyro-electrics, Piezo-electric and Piezo-magnetic rocks -examples of three “smart” materials]

The Early Theoretical Explorers [I primi esploratori teorici]



Julian Schwinger



Giuliano Preparata

Important Issues

Between Schwinger and Preparata, they looked at essentially all aspects of the experimental phenomena and provided possible theoretical reasons

-much more than that by their critics-

- Coulomb Barrier
- Intermittency
- Coherence and Collectivity
- Neutron Haloes
- Resonant Tunneling

The Missing Links [L'Anello Mancante]:

What was missing in the analyses of Schwinger and Preparata?

Two important elements that would be discovered only through experiments after their demise:

- **A: The Japanese CF results showed that all the action is from a few atomic layers near the surface. They are not volume effects.**
- **[Superficie non volume]**
- **B: Neither included the weak**

interactions. Widom would introduce

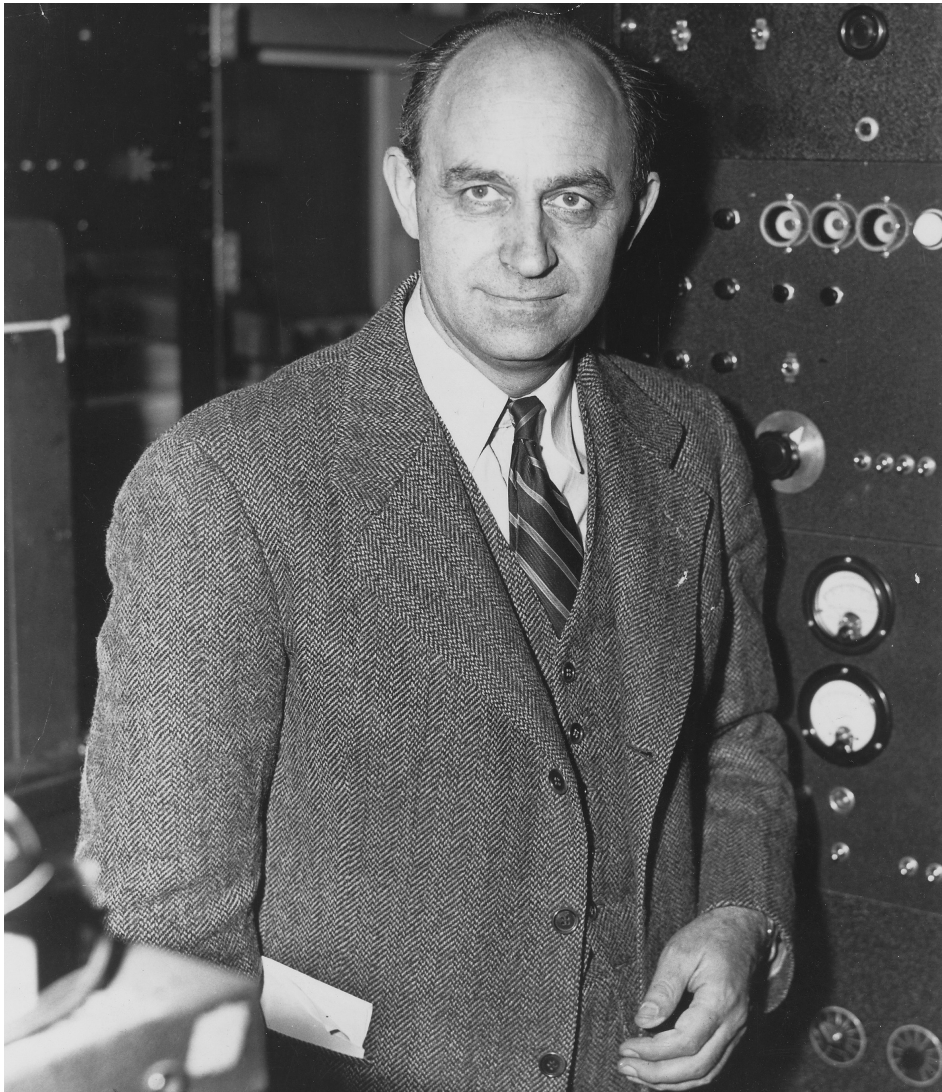
Electro-Weak Induced LENT: WLS Theory I

Widom added the Weak Force for LENT following the Fermi dictum:

Give me enough neutrons
And I shall give you the
Entire Periodic Table

$$n + {}^{A}X_Z \rightarrow {}^{A+1}X_Z + \gamma$$

$${}^{A}Y_Z \rightarrow {}^{A}Y_{Z+1} + e^- + \bar{\nu}_e$$



Electro-Weak Induced LENT: WLS Theory II

Electrons and protons in condensed matter have low kinetic energy and the inverse beta decay [electron capture by Wick]

$$e^- + p \rightarrow n + \nu_e$$

has a Q-value deficit of about 0.78 MeV. This means an energy W≥ 0.78 MeV needs to be put into the system for the reaction

$$W_{in} + e^- + p \rightarrow n + \nu_e$$

to proceed. W can be

(i) Electrical Energy: Widom-Larsen

(ii) Magnetic Energy: Widom-Larsen-Srivastava

(iii) Elastic[Piezoelectric & Piezo-magnetic] Energy: Widom-Swain-Srivastava

We have examples in Nature for all three

Threshold Energy Input for EW LENT

$$W = \gamma \; mc^2$$

$$W > W_{threshold} \sim 1.28 \; MeV$$

$$\downarrow$$

$$\gamma_{threshold} \sim 2.5$$

Lack of this energy in usual condensed matter systems is why we have

Rate of Neutron Production

- Once the threshold is reached, the differential rate for weak neutron production is

$$\Gamma_2 \approx \left(\frac{3g_V^2 + g_A^2}{2\pi^2}\right)\left(\frac{G_F m^2}{\hbar c}\right)^2\left(\frac{mc^2}{\hbar}\right) n_2 (\gamma - \gamma_{threshold})^2$$

$$\Gamma_2 \approx \varpi\left(\gamma - \gamma_{threshold}\right)^2$$

$$10^{12}\frac{Hz}{cm^2} < \varpi < 10^{14}\frac{Hz}{cm^2}$$

A robust production rate for neutrons

Rome group claims: neutrons unlikely

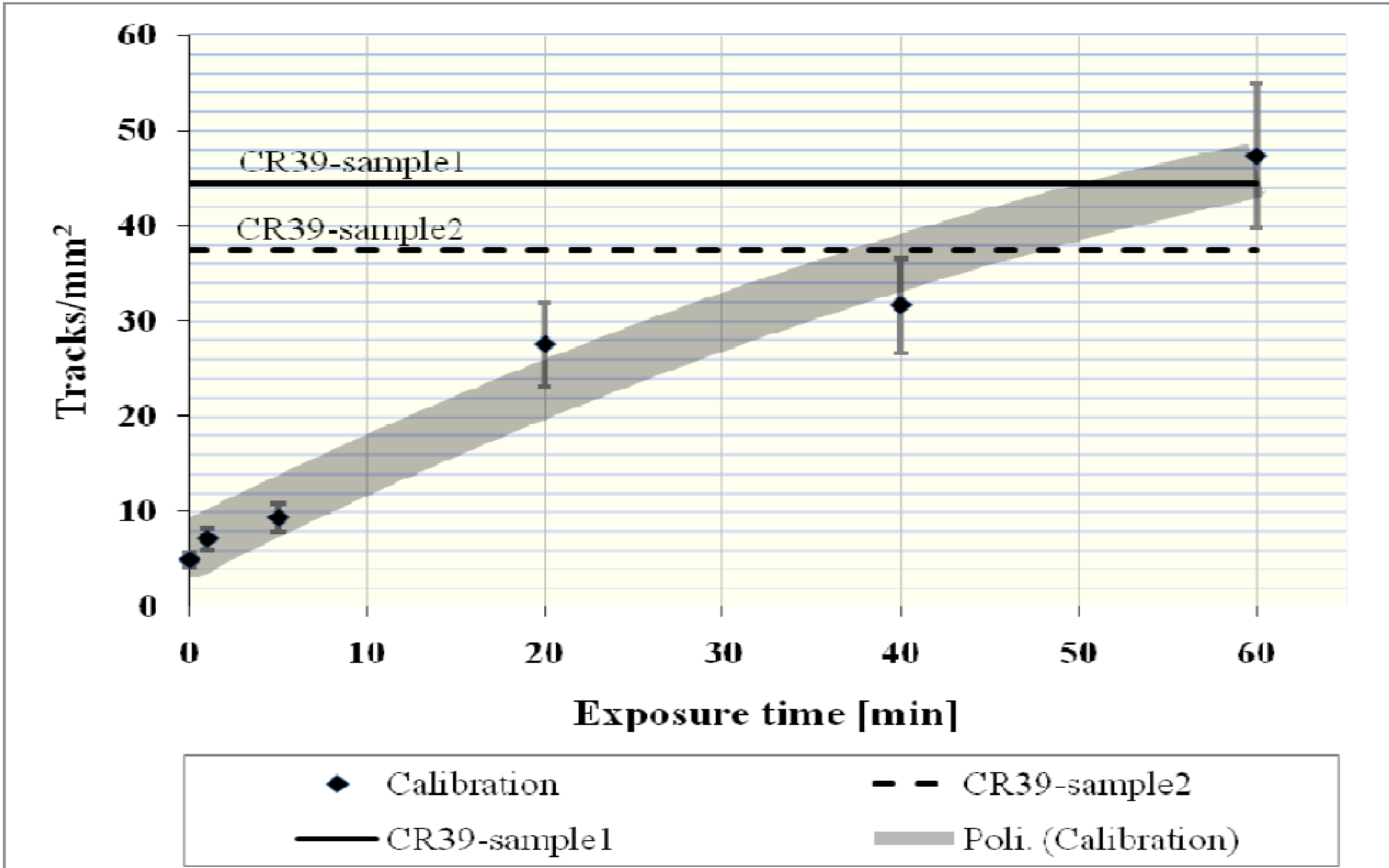
Experimentally Untrue!

Experimental Evidence of Neutron Production in a Plasma Discharge Electrolytic Cell

Domenico Cerillo, Roberto Germano,
V. Tontodonato, A. Widom, YS, E. Del Giudice,
G. Vitiello

Key Engineering Materials, 495 (2012) 104

Plasma Cell XV: Neutron Flux



The Promete Naples Experiment XIV: Evidence for Nuclear Transmutation

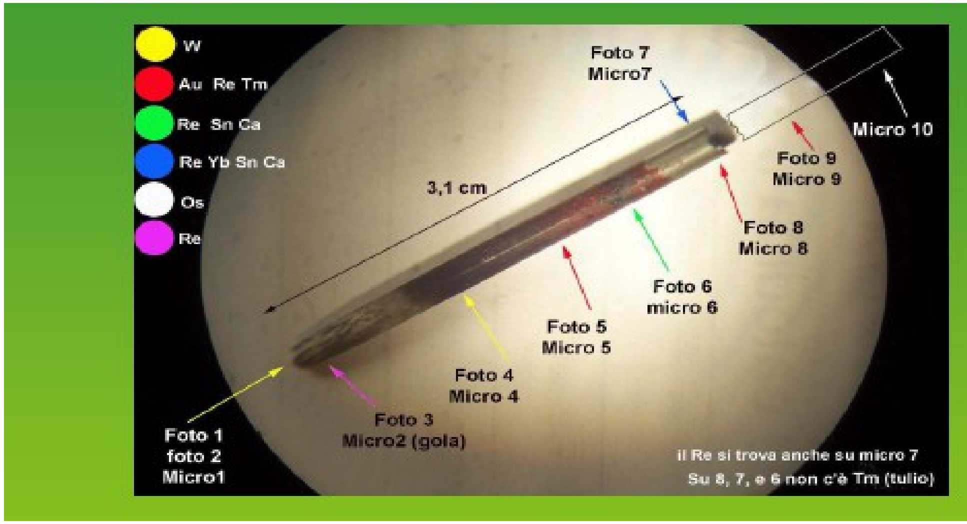
Cathode: Pure Tungsten in K_2CO_3

Substances found afterwards on the surface:

1. Rhenium [always]

With less abundance

2. Osmium
3. Tulium
4. Yttrium
5. Gold
6. Hafnium
7. Strontium
8. Calcium
9. Tin
10. Germanium
11. Zirconium



Electric Field Acceleration

- Excitation of surface plasma modes at a mean frequency Ω, yields a fluctuating electric field *E*. These QED fluctuations renormalize the electron energy $\tilde{e}^{-} + p \rightarrow \ n + \nu$

$$W + M_p c^2 > \ M_n c^2$$

$$W = \gamma(mc^2) = mc^2 \sqrt{1 + (\frac{e^2 \bar{E}^2}{m^2 c^2 \Omega^2})}$$

Electric Field Mode II

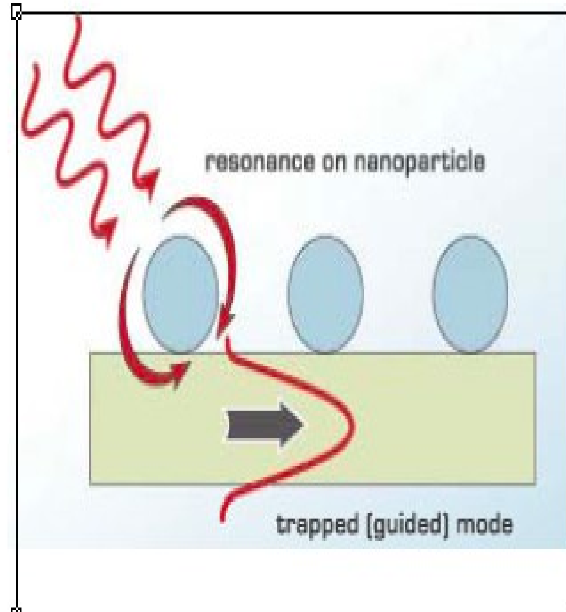
- Electric Mode [W-L]

Surface Plasmon Polariton [SPP] evanescent resonance modes can be set up on a metallic hydride surface generating strong local electric fields to accelerate the electrons

$$W_{electric} + e^- + p \rightarrow n + \nu_e$$

$$\Omega$$

$$\frac{c\mathcal{E}}{\Omega} = \frac{mc^2}{e} \approx 0.5 \times 10^6\ Volts$$



4 Acid tests for LENT

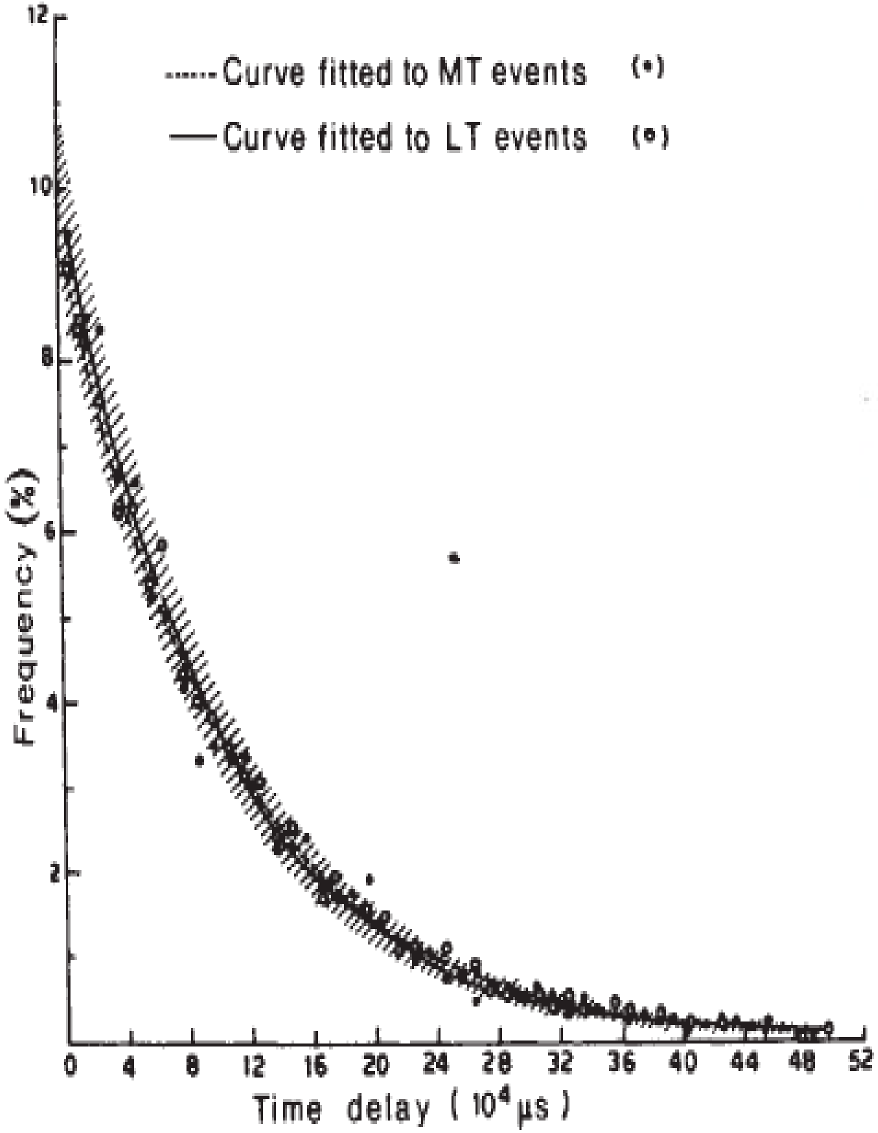
For truly conclusive evidence that LENT has indeed occurred in a given experiment, we must have:

1. EM radiation [gamma's in the (100 KeV-MeV) range]

2. Neutrons must be observed

3. Observance of materials not initially present

LENT in Nature: Neutrons from Lightning



NATURE VOL. 313 28 FEBRUARY 1985 LETTERS TO NATURE 773

Neutron generation in lightning bolts

G. N. Shah, H. Razdan, C. L. Bhat* & Q. M. Ali

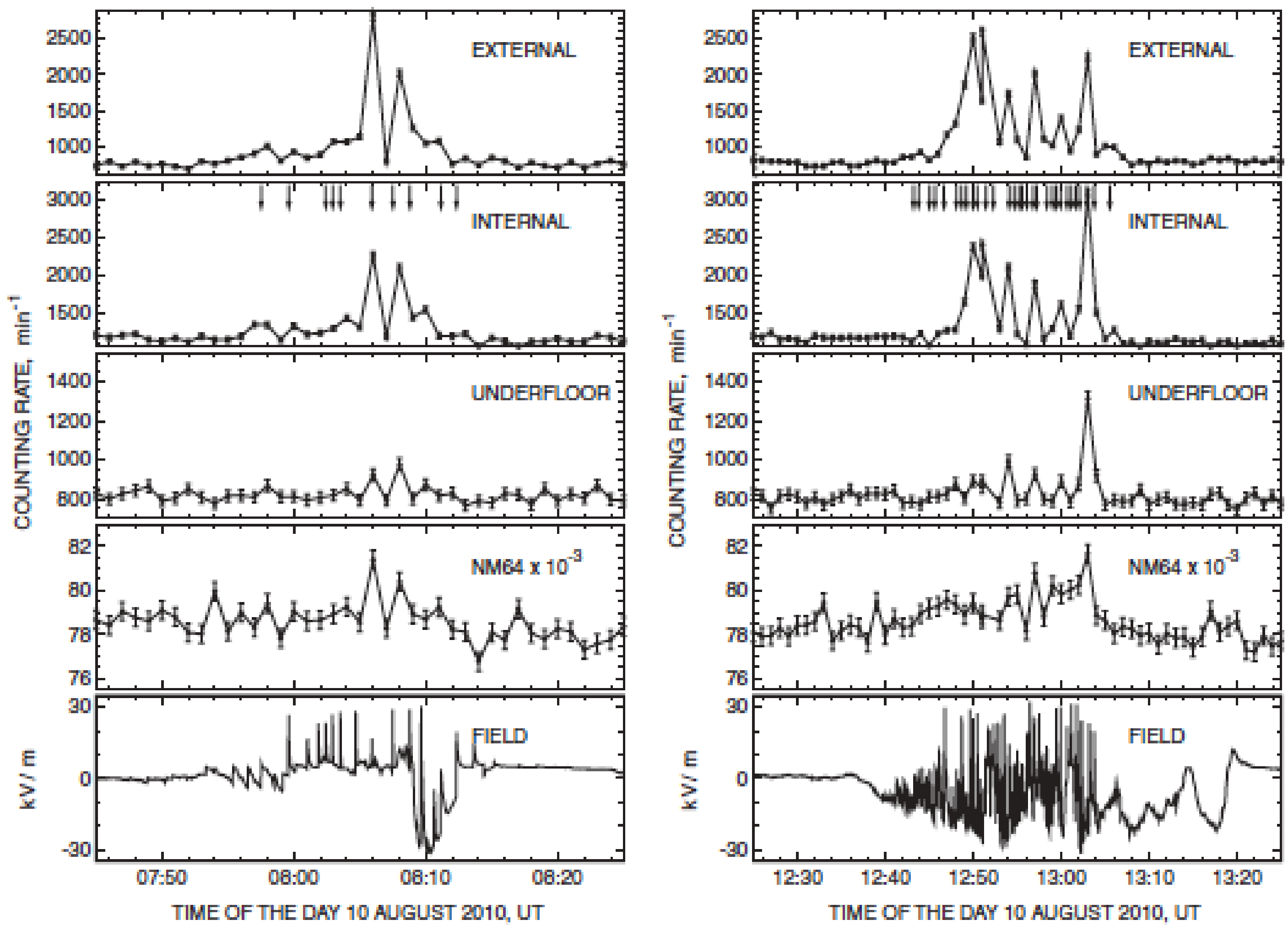
Bhabha Atomic Research Centre, Nuclear Research Laboratory, Zakura, Naseem Bagh, Srinagar-19006, Kashmir, India

Mean Current about 35 Kilo Amperes

(I/Io) ~ 2

Strong Flux of Low Energy Neutrons Produced by Thunderstorms

A. Gurevich *et al*: Phys. Rev. Lett. 108, 125001; 23 March(2012).



Strong flux of neutrons from thunderstorms II

Salient results and conclusions derived by the experimentalists:

- Most of the observed neutrons are of low energy in contrast to cosmic ray measurements where higher energy neutrons dominate.
- Measured rates of neutrons are anomalously high and to accommodate them an extra ordinarily large intensity of radiation in the energy range (10–30) MeV, of the order of (10–30) quanta/ cm2 /sec. is needed to obtain the observed neutron flux.
- The obtained γ- ray emission flux was about 0.04 quanta/ cm2 /sec., 3 orders of magnitude less than the needed value.

- In all these observations the radiation intensity was observed at moderate energies (50–200) KeV [3 orders of magnitude lower than that needed]

Strong flux of neutrons from thunderstorms III [Widom-Swain-YS]

We show that the source of a strong neutron flux at low energy is not theoretically anomalous.

The explanation, employing the standard electroweak model, as due to the neutron producing reaction

$$e^- + p^+ \to \ n + \nu_e$$

which is energetically allowed via the large high current electron energy renormalization inside the core of a lightning bolt.

Strong flux of neutrons from thunderstorms IV

- Consider an initially large number (N +1) of interacting electrons contributing to the electric current within the lightning bolt undergoing a weak process

$$(N+1)e^- + p^+ \rightarrow (N)e^- + n + \nu_e$$

- The importance of having a large number of “spectator” electrons is the induction of a coherent Darwin interaction between the electrons.

- Although only one electron disappears, many electrons are required to yield a high collective contribution to the reaction energy which thereby enhances the nuclear activity. We have shown that the

Large values of the parameter Gamma

Rome group claims that maximum:

$$\gamma \approx \ (2 \div 3)$$

Experimentally untrue: With laser wakefields

1. Imperial College (2004) $\gamma \approx \ 140$
2. Berkeley (2004): $\gamma \approx \ 170$
3. LOA, France (2004): $\gamma \approx \ 340$
4. Berkeley (2006) $\gamma \approx \ 2000$

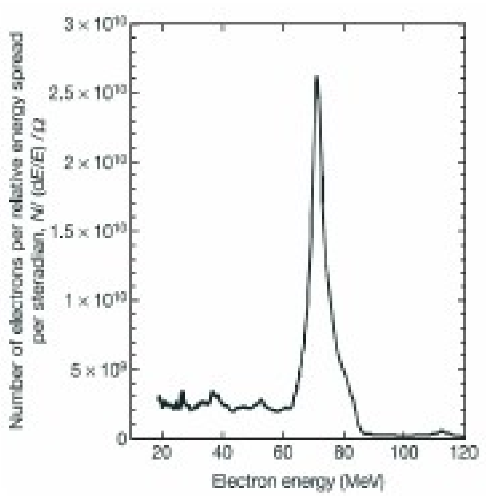
DREAM BEAMS by FAST LASERS I

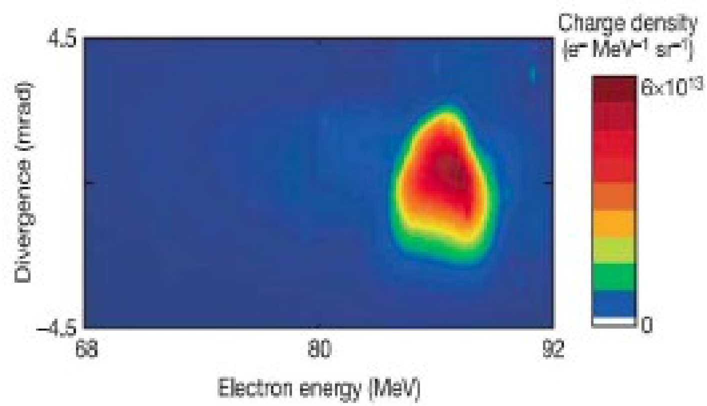
2nd Session – Experiments performed Multi-TW table top laser systems – Recent historical landmarks – First Mono-Energetic LWFA experiments

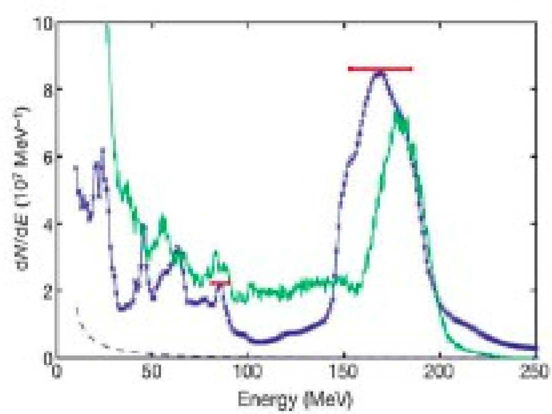
Mangles et al, Imperial College, UK: 70 MeV beam

Geddes et al, Lawrence Berkeley, USA: 85 MeV beam

Faure et al, LOA, France: 170 MeV beam







All images taken from Nature, 431

DREAM BEAM

DREAM BEAM II

2nd Session – Experiments performed Multi-TW table top laser systems – Recent historical landmarks – First Mono-Energetic GeV experiment

Leemans et al,
Lawrence Berkeley, USA:
1000 MeV beam

Long interaction length, i.e. 33 mm, via guiding through a Hydrogen filled, discharge capillary

Note : Maximum electron acceleration ~ 100 GeV in km long linear accelerators

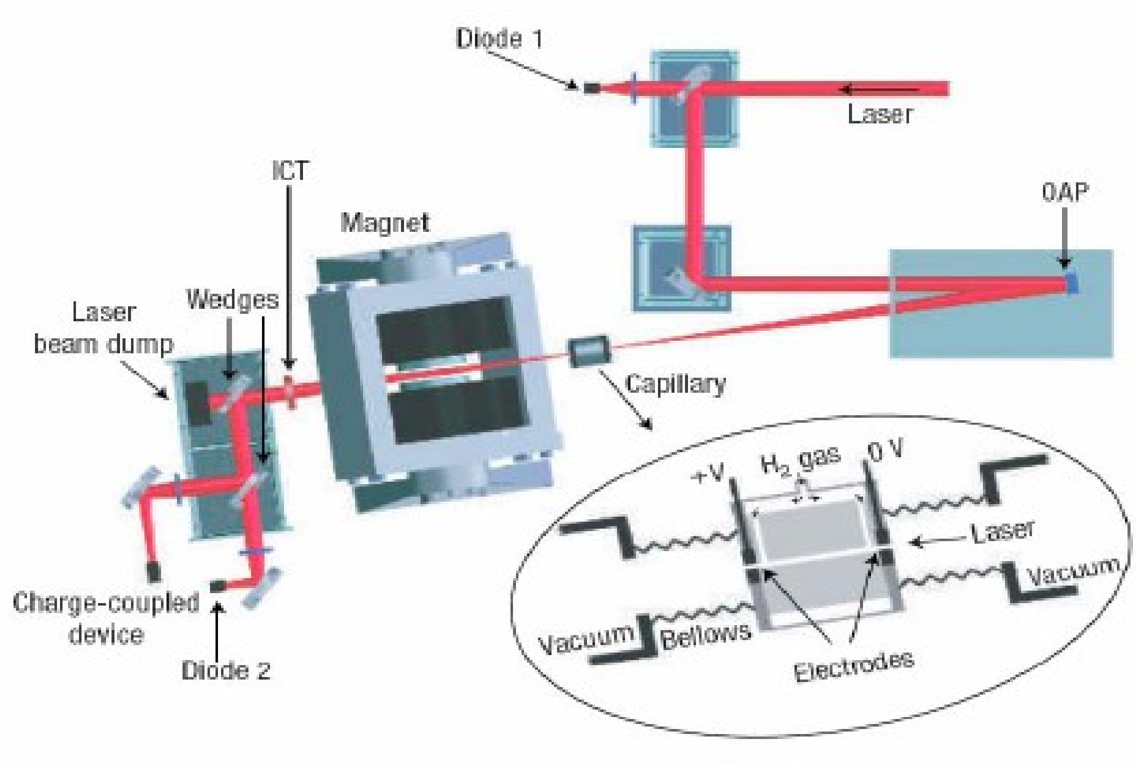
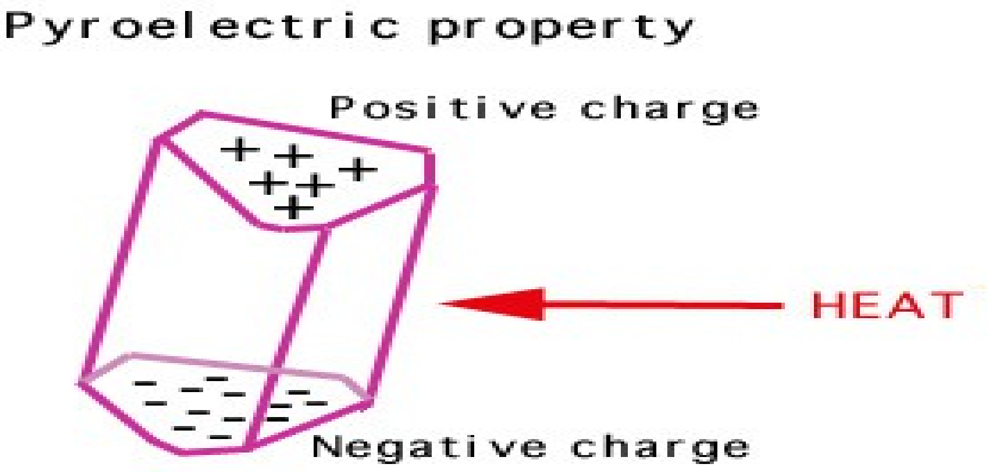


Image taken from Leemans et al., Nature Physics, 2 (2006)

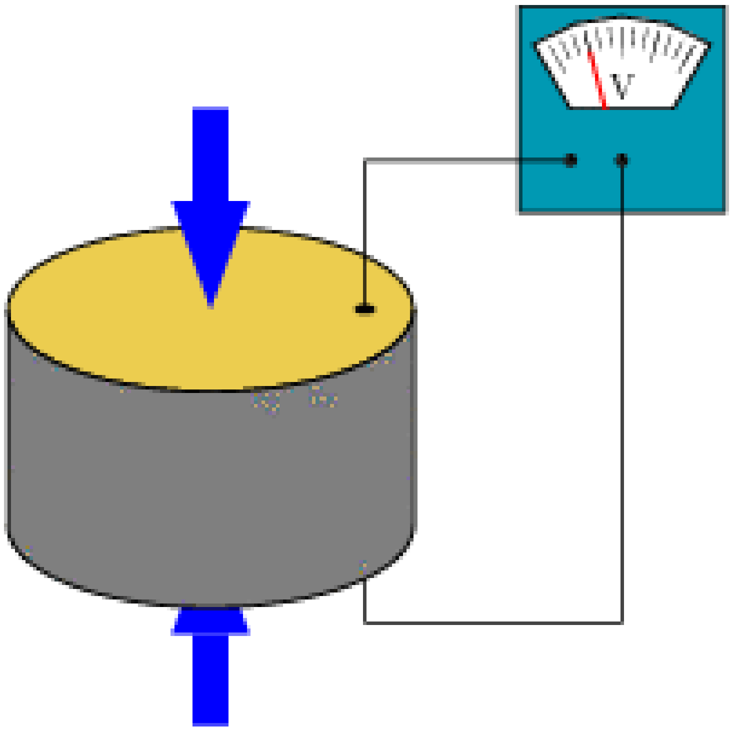
Two Smart Materials

1. Pyroelectric crystals: when heated or cooled produce electric fields



2. Piezoelectric crystals when crushed produce electric fields

Piezoelectric Solids



Strains in a crystal produce voltages across the crystal and vice versa.

Magnetite: piezomagnetic material

Magnetic counterpart of a piezo-electric material

Elastic energy is converted into Magnetic energy

Neutron production from fracturing “Smart” rocks [WSS]: I

- Theoretical explanation is provided for the experimental fact that fracturing piezoelectric rocks produce neutrons

- The mechanical energy is converted by the piezoelectric effect into electrical energy

In a piezoelectric material [quartz, bone, hair, etc.], forming a class called “smart materials”, conversion of

elastic energy $\leftrightarrow$ electrical energy

can occur

Neutron production from fracturing rocks [WSS]: II

$\mathcal{E}$ Electric field

w Strain tensor

β Piezoelectric constant

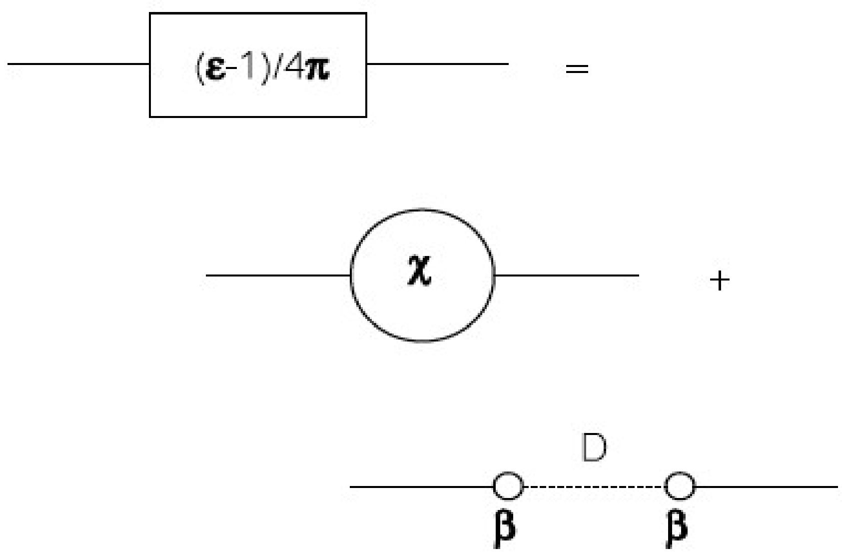
$$\mathcal{H}_{int} = -\int \beta_{ijk} E_i w_{jk} d^3\mathbf{r}$$

Neutron production from fracturing rocks [WSS]: III

$$\mathbf{D} = \mathbf{E} + 4\pi\mathbf{P},$$

$$\epsilon_{ij}(\zeta) = \delta_{ij} + 4\pi\tilde{\chi}_{ij}(\zeta),$$

$$\tilde{\chi}_{ij}(\zeta) = \chi_{ij}(\zeta) + \beta_{i,jk} D_{lknm}(\zeta) \beta_{j,nm}$$



- *Dijkl* is the phonon propagator
- εij is the dielectric response tensor; it appears in the polarization part of the photon propagator
- The Feynman diagram shows how the photon propagator is affected by βijk
- The above makes us understand why mechanical acoustic frequencies occur in the electrical response of piezoelectric materials

Neutron production from fracturing rocks [WSS]: IV

Numerical Estimates:

(i) vs velocity of sound vs. c is ~ 10-5 hence

(ωphonon /ωphoton) ~ 10-5 for similar sized cavities

(ii) The mean electric field E ~ 105 Gauss

(iii) The frequency of a sou e is

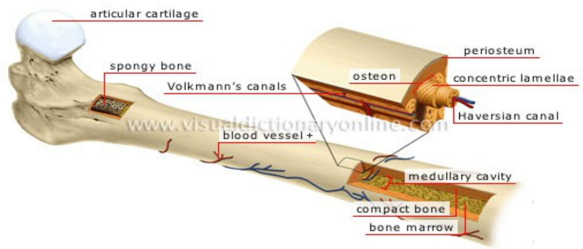
$$\Gamma(e^- + p^+ \rightarrow n + \nu_e) \sim 0.6\ \mathrm{Hz} \qquad \varpi_2 \sim 10^{15} \frac{\mathrm{Hz}}{\mathrm{cm}^2} \ .$$

in the microwave range

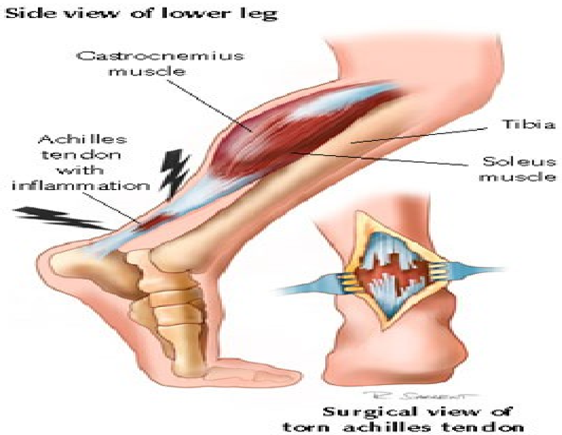
LENT in Smart Materials I: Pyroelectrics

A pyroelectric crystal develops an electric field due to (adiabatic) changes in its temperature and its opposite: an applied electric field causing an adiabatic heating or cooling of the system is called the electrocaloric effect.

Examples of natural pyroelectric crystal are: tourmaline, bone, tendon.



It was experimentally shown that pyroelectric crystals when heated or cooled produced nuclear dd fusion evidenced by the signal of 2.5 MeV neutrons. The system was used to ionize the gas and accelerate the ions up to 200 KeV sufficient to cause dd fusion. The measured yields agree with the calculated yields.



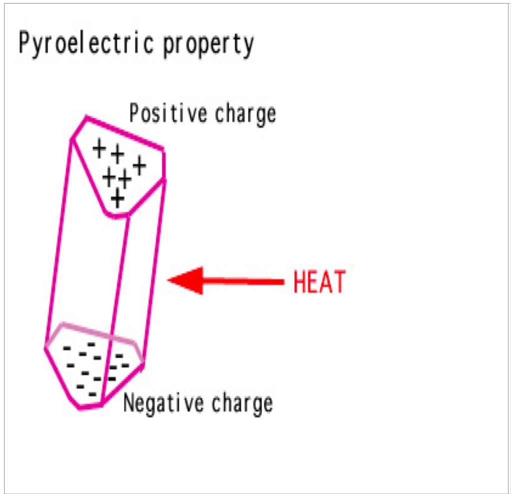
Pyroelectrics II

- In a single domain of a pyro-electric crystal, the mean electric induction is not zero:

$$< \mathbf{D} > \neq 0$$

- When such a crystal is heated or cooled, it gets spontaneously polarized: produces an electric field
- The effective electric field (Eeff) generated in the crystal is assumed proportional to the change in the temperature (ΔT): Eeff = $\phi\ \Delta T$
- Lithium Tantalate [LiTa03] has a large

$$\phi = 17 \text{ KV/cm K}$$



Pyroelectrics III

- The energy given to an ion of charge e may be written as $eV = 4\pi e t\, \phi(\Delta T)/\varepsilon$ [t is the thickness; ε is the dielectric constant]
- For a two Lithium tantalate crystal set up, each 1 cm thick, $\varepsilon = 46$, $\Delta T = 100$ C, the energy should be

$$E = (2\ e)\ \text{Voltage} = 933\ \text{KeV}$$

- Instead the measured value is 200 KeV [In the core of the Sun it is only about 1.5 KeV]
- This energy is much more than sufficient for say two accelerated deuterons to overcome the Coulomb repulsion and cause fusion.
- Pyro fusion has been observed in several

Pyroelectrics IV

$$d + d \rightarrow {}^3\mathrm{He} + n$$

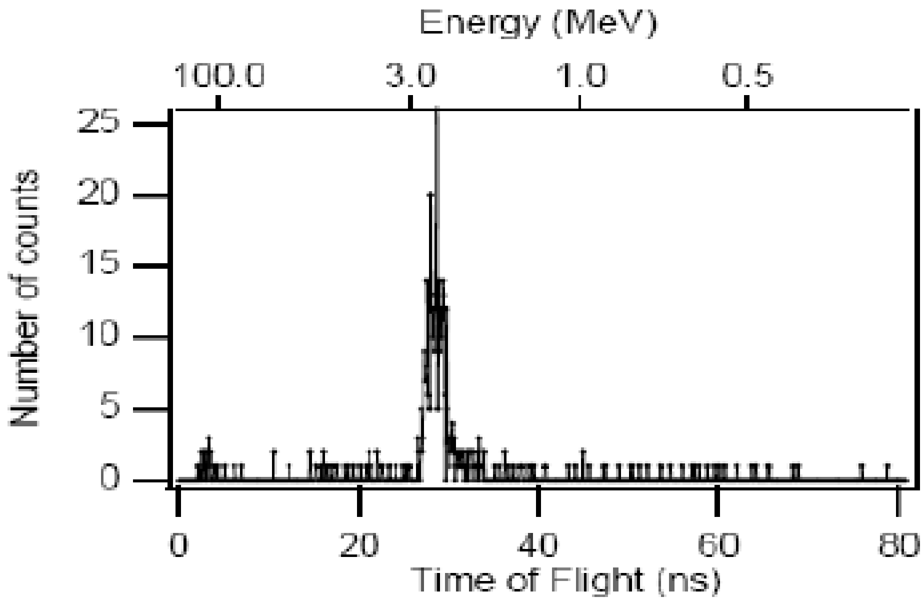


FIG. 1. Neutron time-of-flight spectrum. Neutrons were detected 62 cm from the target using a 7 mm thick plastic scintillator. The peak occurs at 2.45 ± 0.2 MeV, characteristic of DD fusion.

Electro-strong LENT I

Electro-strong Nuclear Disintegration in Matter

J. Swain, A. Widom and Y. Srivastava

arXiv: 1306.5165 [nuc-th] 19 June 2013

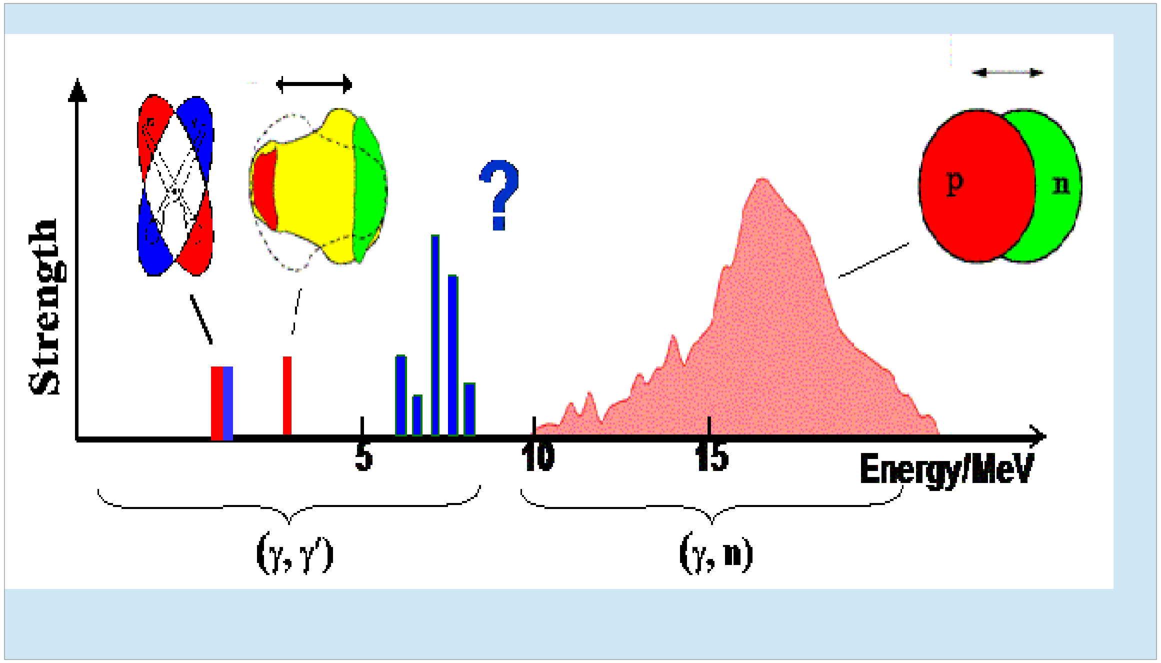
arXiv: 1306.6286 [phys-gen ph] 25 June 2013

Real photons and virtual photons [from electron scattering] have been used for over 50 years to disintegrate nuclei through giant dipole resonances.

In the past, accelerators have produced the needed [10-50] MeV photons for breaking up nuclei.

Our suggestion: accelerate electrons up to several

Giant Dipole Resonances



- Photons produce a coherent oscillation of protons and neutrons in any nucleus. Well studied since 1945

Electro-strong LENT II

Processes usually studied are 1 & 2 neutron production

$$\gamma + A \rightarrow \; n + A^{*}; \gamma + A \rightarrow \; 2n + A^{**}$$

A* & A** are excited nuclei.

We have a synthesis of electromagnetic and strong forces in condensed matter via giant dipole resonances [GDR] to give an effective

"electro-strong interaction"

- a large coupling of electromagnetic and strong interactions in the tens of MeV range.

Electro-strong LENT III

- GDR are well-studied and represent a strong coupling between all atomic nuclei and photons in the range of (10-25) MeV.
- GDR are well-known to be excited by electrons with a few tens of MeV with significant neutron yields (often 10−3 or more) per electron on thick targets, and both fast and slow neutrons can be produced.
- GDR are very well understood and used, both theoretically and practically in devices well outside the scope of nuclear physics proper [for example in medical physics].

Electro-strong LENT IV

- When electrons are accelerated to tens of MeV in condensed matter systems, then in addition to producing neutrons via electroweak processes, we expect, and at much higher rates, what we call “electrostrong processes”, where nuclear reactions take place mediated by GDR.
- In this case one expects slow neutrons from evaporation of GDR’s as well as some fast ones, and additional nuclear reactions when those neutrons are absorbed.

Electro-strong LENT V

Once electrons are accelerated to tens of MeV in condensed matter systems, then we expect both

endothermic and exothermic nuclear fission

&

appearance of new nuclei

due to further reactions of the decay products including subsequent decays and/or the absorption of

Electro-strong LENT VI

- AN EXAMPLE: ALUMINUM AND SILICON FROM IRON

$$\gamma + ^{56}_{26}Fe \rightarrow \; 2[^{28}_{14}Si + e^- + \bar{\nu}_e]$$

$$\gamma + ^{56}_{26}Fe \rightarrow \; 2[^{27}_{13}Al + n]$$

If electrons are accelerated to several tens of MeV in condensed matter systems containing iron, then one may expect the appearance of aluminum and silicon. Experimental data: A. Carpinteri et al. [Politecnico Torino]

Electro-strong LENT VII

AN APPROXIMATE UNIFICATION OF FORCES AT (10-20) MEV IN CONDENSED MATTER

At tens of MeV, all three forces of the

Standard Model of Particle Physics:

electromagnetic, weak, and strong processes

can all be expected to occur in bulk condensed matter.

The Preparata Project at Perugia

At University of Perugia, we have assembled a group of experimentalists who have begun a set of Proof of Concept experiments to implement and check the theoretical results obtained by our group.

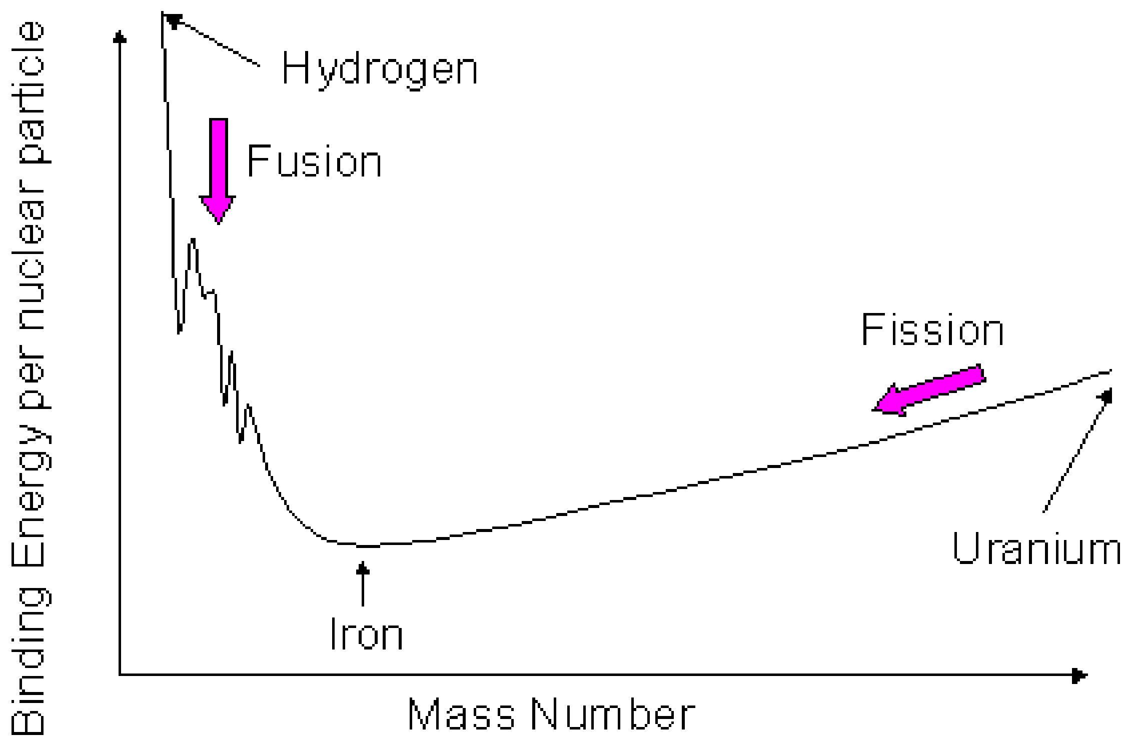
We have a 3-year doctoral candidate [EM] and a Laurea Specialistica student and we are expecting to add a Post-doctoral researcher depending upon the availability of funds.

Research support is currently being provided by CNP, Switzerland

Giuliano Preparata
(1942-2000)

Synthesis of Electroweak & Electrostrong, fulfills the Fermi dictum to reproduce the entire periodic table given enough neutrons.

We dedicate it to the memory of the two J/Gulians:
Julian Schwinger and Giuliano Preparata who worked so hard and suffered so much



Summary and Future Prospects

All interactions of the Standard Model:

EM-Weak-Strong

can act in tandem with coherent oscillations of electrons, protons and neutrons

and cause nuclear reactions in special condensed matter systems when energies (1-20) MeV are reached.

We have experimental evidence for all of these in

"Elegant Soutions. Ten Beautiful Experiments in Chemistry"
by
Philip Ball

Rutherford had teamed up with British chemist Frederick Soddy to find that thorium produced argon:

They realized the implication with something akin to horror.

`The element was slowly and spontaneously transforming itself into argon gas!', Soddy later wrote.

At the time, he was shocked.

Soddy reportedly stammered to his colleague in the lab,

`this is transmutation: the thorium is disintegrating.

`For Mike's sake Soddy', Rutherford thundered back, `don't call it transmutation. They'll have our heads off as alchemists.'

But transmutation was truly what it was.

Which is more likely? Electro-Weak-Strong LENT or this?