# LENT: Low Energy Nuclear Transmutations
# General Theory & Experiments

A lecture to honour two great theoretical physicists
*Julian Schwinger & Giuliano Preparata*
Who paved the way for us to follow

By

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@

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# Outline of the Talk I

Antipasto to Dessert: J. Schwinger & G. Preparata

After Schwinger's personal account of the turbulent history of CF

We shall present experimental evidence & theoretical results to show that all 4 fundamental interactions produce LENT:

1. Sun: The Sun is kept warm and can produce energy through gravitational, nuclear, electromagnetic and weak forces all working together to produce LENT.

2. Strong: When high voltages are applied to very thin deuterated wires and strong currents generated, LENT takes place. Two deuterons fuse into Helium3 and neutrons.

# Contents of the Talk: II

3. Electric LENT: With lasers we can produce large clusters of deuterons.

Large positive charge in a small volume will explode producing a shower of accelerated deuterons. Fast flying deuterons from different clusters will then fuse and produce LENT.

Several labs around the world have done marvelous feats with such techniques: making imaging devices and many applications to biology.

4. Magnetic LENT: In the Solar Corona electrons and protons can get accelerated due to large magnetic fields to produce LENT.

5. *Smart* Materials I: Pyroelectric crystals when heated/cooled produce LENT

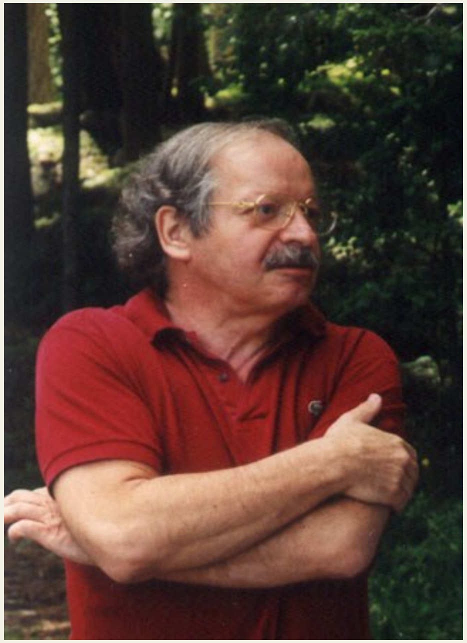
6. *Smart* Materials II: Piezoelectric crystals when crushed produce LENT.

7. Fusors

8. Conclusions & Future Outlook

# The Early Explorers

Julian Schwinger



Giuliano Preparata

# Julian Schwinger wrote 8 papers on CF[1990-94]

## **"Cold Fusion Theory: A Brief History of Mine"**

**"As Polonious might have said:**

**"Neither a true-believer nor a disbeliever be."**

**Schwinger asked himself**

**"*not* whether Pons and Fleischmann were right**

**–but whether a mechanism could be identified that will produce nuclear energy by manipulations at the atomic–the chemical–level.**

**Of course, the acceptance of that interpretation of their data is needed as a working hypothesis, in order to have quantitative tests of proposed mechanisms."**

# Schwinger II: Major Objections to CF

"I do not have to, but shall, remind you of the two fundamental problems that the acceptance, of Pons and Fleischmann's excess heat as nuclear in origin, entails."

1. What accounts for the absence of particles that are familiar in ordinary hot fusion, such as the neutrons of

$$D + D \rightarrow \; n +^3 He$$

and the high energy $\gamma$-ray of D + D--> $\gamma$ + $^4$He?

"Very early in my thinking I added the conventional reaction

p + D--> $\gamma$ + $^3$He. Why?

Mostly because it would also be there. One cannot produce heavy water without some contamination by light water.

[My remark: this would later play an essential role for an entirely different reason]

# Schwinger III: Coulomb Repulsion & Innuendoes

**2. Hot fusion relies on achieving enough kinetic energy to overcome the Coulomb repulsion between like charges. How then can cold fusion, operating far below those levels, ever achieve fusion?**

***"Incidentally, I have read, and heard, that my solution to the Coulomb barrier problem is to forget it! Not even an absent-minded professor (which I am not) would go that far.***

***"Critics should learn to operate within the bounds of sanity."***

# Schwinger IV: Contemptuous Reviewers

**“My first attempt at publication, for the record, was a total disaster. "Cold Fusion: A Hypothesis" was written to suggest several critical experiments, which is the function of hypothesis.**

**“The masked reviewers, to a person, ignored that, and complained that I had not proved the underlying assumptions.**

***Has the knowledge that physics is an experimental science been totally lost?***

**The paper was submitted, in August 1989, to PRL….**

**“What I had not expected–as I wrote in my subsequent letter of resignation from the American Physical Society**

***–was contempt***

# Schwinger V: $D_2O$ vs $H_2O$

"Hypothesis" was eventually published, after protracted delays, in a 1990 issue of a German periodical.

"... this cold fusion process (of P & F) is not powered by a DD reaction. Rather it is an HD reaction, which feeds on the small contamination of $D_20$ by $H_20$

"The HD reaction p + d --> $^3$He does not have an accompanying $\gamma$-ray; the excess energy is taken up by the metallic lattice of Pd alloyed with D."

"... concerning the oft repeated demand for a control experiment using $H_20$, one should note the possibility of a converse effect of the HD reaction: Through the natural presence of $D_20$ in ordinary water, such control experiments might produce an otherwise puzzling amount of heat."

# Schwinger VI: The Fix

- **From another paper, "Nuclear Energy in an Atomic Lattice", is a quotation from Joseph Priestley**:
- **"In this business, more is owed to what we call chance —that is, to the observation of events arising from unknown causes-than to any preconceived theory."**
- **“The editor thought it necessary to add a total disclaimer of responsibility, ending with: "We leave the final judgment to our readers."**
- **“In my naiveté I had thought that was always so.**
- **“When part 2 of the paper was submitted, it was simply rejected.**

**“The fix was in.”**

# Schwinger VII: Getting nowhere with good physics

- **"The HD hypothesis–of the dominance of the pd reaction–has the pragmatic advantage of suppressing neutron production at the level of excess heat generation.**
- **"... a well trained hot fusioneer will instantly object that there must also be a 5.5 MeV $\gamma$-ray. He will not fail to point out that no such radiation has been observed. Indeed."**
- **"But consider the circumstances of cold fusion. At very low energies of relative motion, the proton and deuteron of the HD reaction are in an s-state, one of zero orbital angular momentum, and therefore of positive orbital parity. The intrinsic parities of proton, deuteron, and $^3$He are also positive. Then, the usually dominant electric dipole radiation—which requires a parity change—is forbidden."**
- **[My remark: This is Maestro at his best. No critic to my knowledge has ever considered it, let alone rebut it]**

# Schwinger VIII: Intermittency & the Lattice

- In 1990, Schwinger went to Tokyo for the 100th birthday of Nishina and delivered a lecture on: "Cold Fusion Does It Have a Future?"
- "The case against the reality of cold fusion is outlined. It is based on preconceptions inherited from experience with hot fusion. That cold fusion refers to a different regime is emphasized. The new regime is characterized by intermittency in the production of excess heat, tritium, and neutrons. A scenario is sketched, based on the hypothesis that small segments of the lattice can absorb released nuclear energy."
- "If the $\gamma$-rays demanded by the hot fusioneers are greatly suppressed, what agency does carry off the excess energy in the various reactions?
- "One must look for something that is characteristic of cold fusion, something that does not exist in the plasma regime of hot fusion. The obvious answer is: the lattice in which the deuterium is confined.

# Schwinger IX: Loading

- **"Imagine then, that a small, but macroscopic piece of the lattice absorbs the excess energy of the HD or DD reaction. I advance the idea of the lattice playing a vital role as a hypothesis.**
- **"Intermittency is the hallmark of cold fusion... Does the lattice hypothesis have a natural explanation for intermittency?" [My remark: Intermittency is a well known experimentally observed phenomenon in high energy multi particle production]**
- **"A close approach to saturation loading is required for effective fusion to take place."**
- **"But, surely, the loading of deuterium into the palladium lattice does not occur with perfect spatial uniformity. There are fluctuations."**

# Schwinger X: Burst & Shut-down

- **"It may happen that a microscopically large–if macroscopically small–region attains a state of such lattice uniformity that it can function collectively in absorbing the excess nuclear energy that is released in an act of fusion.**
- **And that energy can initiate a chain reaction as the vibrations of the excited ions bring them into closer proximity. So begins a burst.**
- **In the course of time, the increasing number of vacancies in the lattice will bring about a shut-down of the burst.**
- **The start-up of the next burst is an independent affair. (This picture is not inconsistent with the observation of extensive cracking after long runs.)"**

# Schwinger XI: Recommends East

- **Schwinger's gloom deepens:**
- **"I have little hope for it in Europe and the United States—the West. It is to the East, and, specifically, to Japan that I turn." [My remark: He has been proven right]**
- **In a third paper, "Nuclear Energy in an Atomic Lattice-Causal Order"**
- **"The extremely small penetrability of the Coulomb barrier is generally adduced to dismiss the possibility of low energy (cold) fusion. The existence of other mechanisms that could invalidate this logic is pointed out."**
- **"... Implicit in this line of thought (of negligible penetrability) is the apparently self-evident causality assignment that has the release into the surrounding environment, of energy at the nuclear level occur, after the penetration of the Coulomb barrier.**
- **"One would hardly question that time sequence when the environment is the vacuum.**

# Schwinger XII: Who is on First?

- *"But does it necessarily apply to the surrounding ionic lattice? Another reading is possible, one in which the causal order is reversed. Why?"*
- *"Because, in contrast with the vacuum, the lattice is a dynamical system, capable of storing and exchanging energy.*
- **"The initial stage of the new mechanism can be described as an energy fluctuation, within the uniform lattice segment, that takes energy at the nuclear level from a pd or dd pair and transfers it to the rest of the lattice, leaving the pair in a virtual state of negative energy**....
- **"For the final stage ... consider the pd example where there is a stable bound state: $^3$He. If the energy of the virtual state nearly coincides with that of $^3$He, a resonant situation exists, leading to amplification, rather than Coulomb barrier suppression." [My remark: Read Resonant Tunneling. More on it later]**
- **"It would seem that two mechanisms are available ... But are they not extreme examples of mechanisms that in general possess no particular causal order?"**

# Schwinger XIII: Coherence

- **"This representation [first barrier penetration, then nuclear reaction]... may be true enough under the circumstances of hot fusion."**
- **"But, in very low energy cold fusion one deals essentially with a single state, or wave function, all parts of which are coherent. It is not possible to totally isolate the effect of the electric forces from that of the nuclear forces: The correct treatment of cold fusion will be free of the collision-dominated mentality of the hot fusioneers."**

# Schwinger XIV: Phonons

- **Schwinger went on to develop a new "Phonon Representation"**
- **"The gap between the non localized lattice phonon description and the localized Einstein oscillator treatment is filled by transforming the phonon Hamiltonian back to particle variables. The particle-coordinate, normalized wave function for the phonon vacuum state is exhibited."**
- **A month later, Schwinger wrote "Phonon Dynamics."**
- **"An atomic lattice in its ground state is excited by the rapid displacement and release of an atomic constituent. The time dependence of the energy transfer to other constituents is studied..."**

# Schwinger XV: Mossbauer

- And then Schwinger went on to develop the "Phonon Green's Function.": [My remark: The Maestro is extending to the phonon case, developments in his earlier seminal papers "The Greening of Field Theory" done after his QED work]
- "The concepts of source and quantum action principle are used to produce the phonon Green's function appropriate for an initial phonon vacuum state. An application to the Mössbauer effect is presented."
- Schwinger reminded us that the Mössbauer effect refers to
- "an excited nucleus of an atom, imbedded in a lattice, (that) decays with the emission of a $\gamma$-ray, thereby transferring momentum to the lattice.

# Schwinger XVI: Das ist Falsch

- **"There is a certain probability ... that the phonon spectrum of the lattice will remain unexcited, as evidenced by the absence, in the γ-ray energy, of the red-shift associated with recoil energy."**
- **"A casual explanation of the Mössbauer effect has it that the recoil momentum is transferred to the lattice as a whole so that the recoil energy, varying inversely with the mass of the entire lattice, is extravagantly small.**
- **As Pauli would say, even to God, "Das ist falsch!"**
- **"The spontaneous decay of a single excited atom in the lattice is a localized event, the consequences of which flow at finite speed, out into three dimensional space, weakening as they travel." [My remark: Giuliano came to the same conclusion]**

# Schwinger XVII: Flaws

- **"This is a microscopic event, with no dependence on macroscopic parameters such as the total mass of the lattice." [My remark: I totally agree with the Maestro that the usual explanation is flawed.]**
- **"What happens if the momentum impulse ... is applied, not to one, but all lattice sites?"**
- **The reader is invited to**
- **"recall that the lattice geometry is not absolute, but relative to the position of the center of mass for the entire system. Thus the injected energy can be read as the kinetic energy transferred to the lattice as a whole."**

# Schwinger XVIII: Heat &/ Helium

- **Schwinger entertains here the interesting possibility that**
- **“the $^3He$ produced in the pd fusion reaction may undergo a secondary reaction with another deuteron of the lattice, yielding $^5Li$ (an excited state of $^5Li$ lies close by). The latter is unstable against disintegration into a proton and $^4He$. Thus, protons are not consumed in the overall reaction, which generates $^4He$." [My remark: In more modern parlance, he is speaking about the now well studied neutron halo states. More on this later.]**

- **Schwinger notes in 1992**,
- **“that observations of $^4He$, with insufficient numbers to account for total heat generated, are consistent with the preceding suggestion.**

- **“The initial pd reaction produces heat, but no $^4He$**.

- **The secondary reaction generates heat and $^4He$**.

- **There may be more total heat than can be accounted for by $^4He$ production. The smaller the ratio of secondary to primary rates, the more the $^4He$ production will be incapable of accounting for the heat generation.”**

# Later Developments I

- Practically all of the subsequent theoretical results will be employing and building on these ideas. Between Schwinger and Preparata, they looked at essentially all aspects of the experimental phenomena and possible theoretical reasons -much more than that by their critics:
- Coulomb Barrier
- Intermittency
- Coherence and Collectivity
- Neutron Haloes
- Resonant Tunneling
- Lattice
- Missing neutrons and $^{4}$Helium
- Other channels: Branching ratios
- Loading
- Burst; Shut-down; Cracking

# The Missing Links:

**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.**
- **B: Neither included the weak**

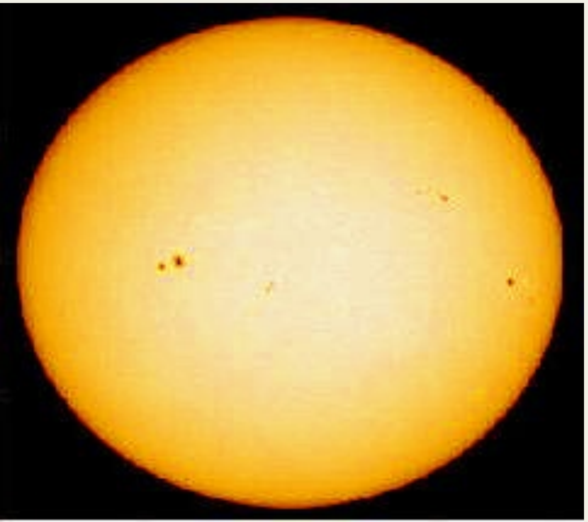
**interactions. Widom would introduce**

**that.**

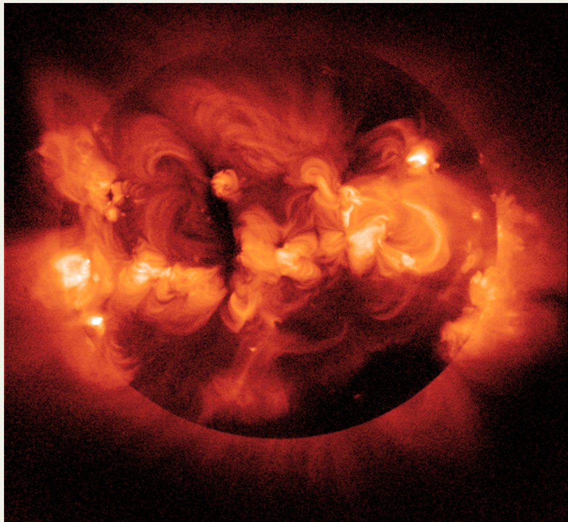
The Sun provides the energy without which no life on Earth would be possible

Question: But who provides the energy which sustains the Sun?

Answer: All four fundamental interactions (forces) known to us [Gravitational, Strong, Electromagnetic and Weak] are necessary to keep the Sun warm.
They lead to Low Energy Nuclear Transmutations [LENT]
Without it the Sun even if somehow started would have spent its fuel and
perished long ago.



Also: which picture (left) or (right) is correct for the surface of the Sun?



arXiv 1211.0924v1 [phys gen-phys] October 27, 2012

Allan Widom, John Swain, YS

# Our Basic Result:

All fundamental interactions
Gravitational, Strong, Electromagnetic &Weak
Lead to LENT both in Nature and in the laboratory.

- The debate should no longer be about their veracity.
- The challenge now is to use modern technology to find new practical applications of the Standard Model of Particle Physics.
- This is the goal of the Preparata Project at Perugia

# GRAVITATIONAL [STELLAR] LENT I

Helmholtz & Kelvin invoked the Gravitational Interaction to fuel the Sun.

Per gram the Sun radiates

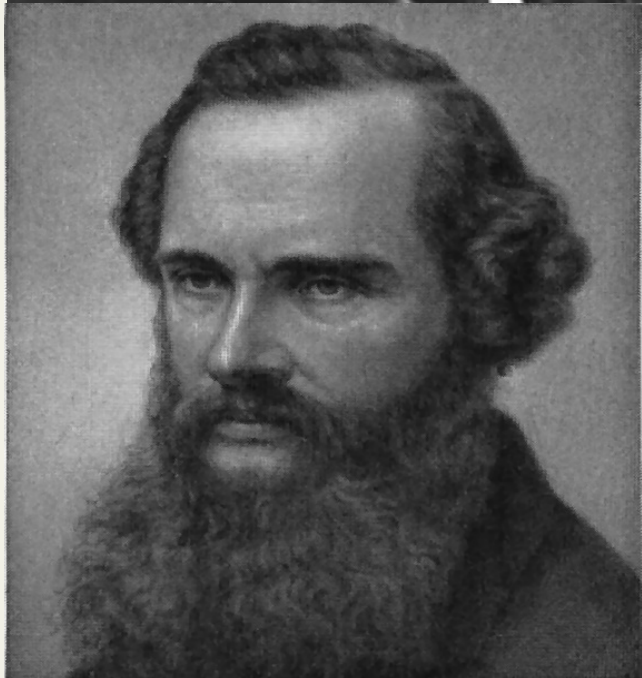
$$\mathcal{F}_{Sun} \approx 1.96 \frac{erg}{gm sec}$$

Newtonian Gravity: Potential Energy/gm

$$\frac{(\Delta E)_{Pot}}{gm} \approx -1.91 \times 10^{15} \frac{erg}{gm}$$

But then the Sun would have radiated away all its energy and lasted only about

**30 million years!**



# Gravitational [Stellar] LENT II

Charles Darwin and other biologists/geologists needed a much longer time span. Hence, they believed H&K must be in error and of course they were right.

In 1895, radioactivity would be discovered and through it the age of the meteors and other objects could be determined.

The age of the Sun is now known to be be about 4.5 billion years. Hence, the gain in energy whatever agency supplies it must be

$$\frac{(\Delta E)_{gain}}{gm} \geq 3.17 \times 10^{17} \frac{erg}{gm}$$

So if not gravity, which one: strong, EM or Weak provides the energy to keep the Sun warm?

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# A footnote about Darwin & Kelvin

1. Lord Kelvin went to University at age 10&1/2!
2. Charles Darwin's father was of the opinion that his son had wasted his time as a student at Cambridge…..
3. Kelvin was the reigning physicist of his time at Cambridge and so his estimate of 30 million years for the Sun put Darwin in great agitation. In his son Francis Darwin's biography, Charles says "Kelvin's ghost stalks me".
4. Later, after Kelvin would be proven wrong, Charles would make the most scathing criticism of a theoretical physicist ever:

A theoretical physicist is like an almost blind man in a dark room looking for a black cat who is not there

# Gravitational[Stellar] III

If all we have are electrons and protons and we want to build other nuclei beginning with a neutron:

EM is **no good** because it can not change the charge;

Strong is also **no good** because even at the centre of the Sun, the kinetic energy of the protons [about 1.46 KeV] is too small.

Hence the only possibility is Weak interactions. Gian Carlo Wick had considered the electron capture reaction

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

But there is a threshold barrier of 0.78 MeV which makes the rate of this process very small. Bethe's estimate for the centre of the Sun is $10^{30}$ years

Given this depressingly low rate,
Von Weizsacker proposed Weak interaction **pp reaction:**

$$p + p \to d + e^+ + \nu_e$$

# Gravitation [Stellar] LENT IV

The gain in energy through the pp reaction

$$\frac{(\Delta E)_{gain}}{gm} = 1.2 \times 10^{17} (\frac{erg}{gm})$$

is quite close to the amount needed.

Armed with this encouraging estimate,

Bethe & Critchfield calculated the rate of the reaction which requires all three interactions of the Standard Model of particle physics:

Weak, EM and Strong interactions:

(i) Coulomb repulsion between two protons

(ii) "Zero" range Fermi interaction to produce a virtual neutron &

(iii) Production of a deuteron through a fusion of proton with a virtual neutron.

# Gravitation [Stellar] LENT IVbis

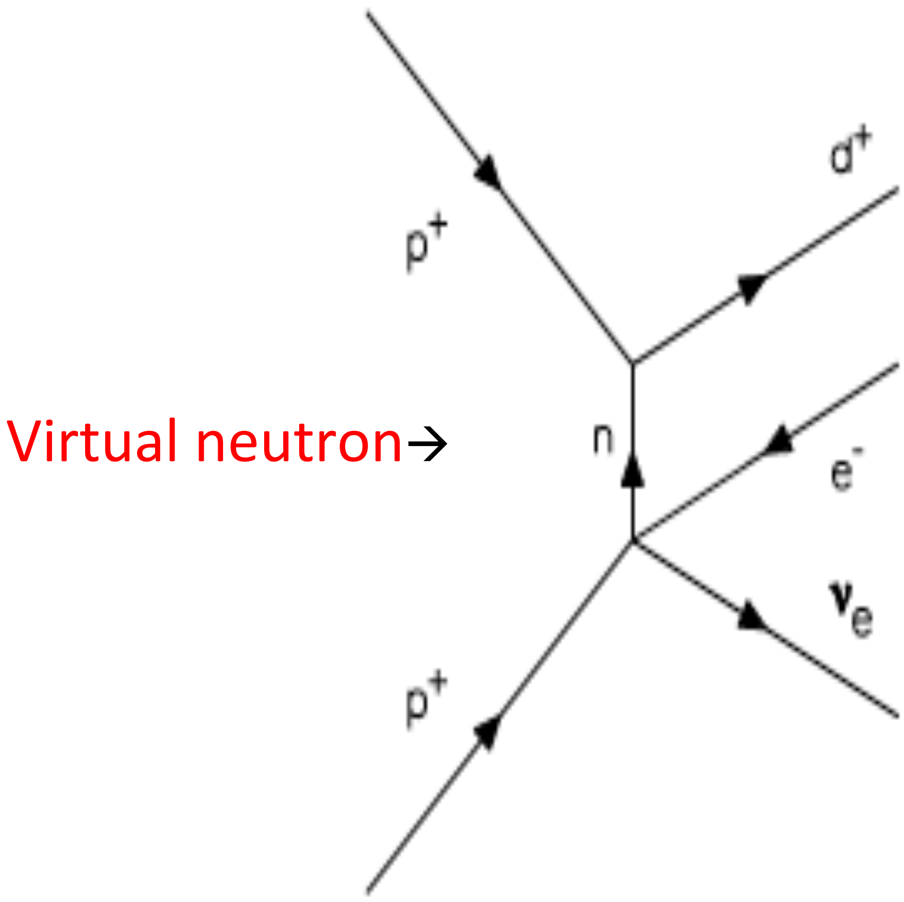



FIG. 1: Shown is the Feynman diagram for the reaction $p^+ + p^+ \to d^+ + e^+ + \nu_e$ as in Eq.(8).

# Gravitational [Stellar] LENT V

The computation of such Coulomb repulsive exothermic reactions is usually expressed as

$$\sigma_{eff}(E) = \frac{S(E)}{E} e^{-\sqrt{E_g/E}}$$

B-C find for the pp reaction: $p + p \to d + e^+ + \nu_e$

$$S[pp \to de^+\nu_e] = 3.36 \times 10^{-25}(MeV - barn)$$

which is very small.

In fact this reaction has never been seen in any Earth laboratory.

# Gravitational [Stellar] LENT VI

2 Deuterons then produce helium3 & neutron:

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

2 Deuterons also produce alpha and radiation:

$$d + d \to^4 \mathrm{He} + \gamma$$

A proton with a deuteron produces helium3 & radiation:

$$p + d \to^3 \mathrm{He} + \gamma$$

Finally von Weiszacker-Bethe process is used twice:

$$p + p + p + p \to^4 \mathrm{He} + e^+ + e^+ + \nu_e + \nu_e$$

No hope of ever seeing this process in an Earth Lab!

# Gravitational [Stellar] LENT VII

Conclusions from the above analysis:

1. All 4 interactions with very different rates of reaction are necessary for the proper functioning of the Sun
2. The most important processes the "pp" & the "pppp" chain have never been verified in an Earth Laboratory yet we believe in it because the theory predicts them.
3. To produce Carbon, Bethe invoked the fusion of three alpha particles: [Never seen on Earth]

$$^4\mathrm{He} + ^4\mathrm{He} + ^4\mathrm{He} \rightarrow ^{12}\mathrm{C}$$

# Gravitational [Stellar] LENT VIII

4. To produce Oxygen, Bethe invoked fusion of Carbon with an alpha

$$^{4}\text{He} + ^{12}\text{C} \rightarrow ^{16}\text{O}$$

Once again never seen on Earth.

Based on theoretical faith, science administrators, chiefs of national and international funding have supported Hot Fusion on Earth for over 60 years with over 200 billion Euros with scarce results.

Yet, when physicists [& Journalists] usually discuss LENT they forget these important lessons

# Strong [Nuclear] LENT I

Several laboratories have observed strong fusion

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

in very thin deuterated polyethylene wires through clean signals of 2.5 MeV neutrons.

As discussed earlier the strong Coulomb repulsion between the deuterons impedes this process in the vacuum and only near the center of the Sun, due to high temperatures, this reaction occurs.

Use of electrical methods instead of high temperatures can and have been made. Very high voltages were employed to successfully accelerate the deuterons to overcome the Coulomb barrier and cause fusion.

# Strong (Nuclear) LENT II

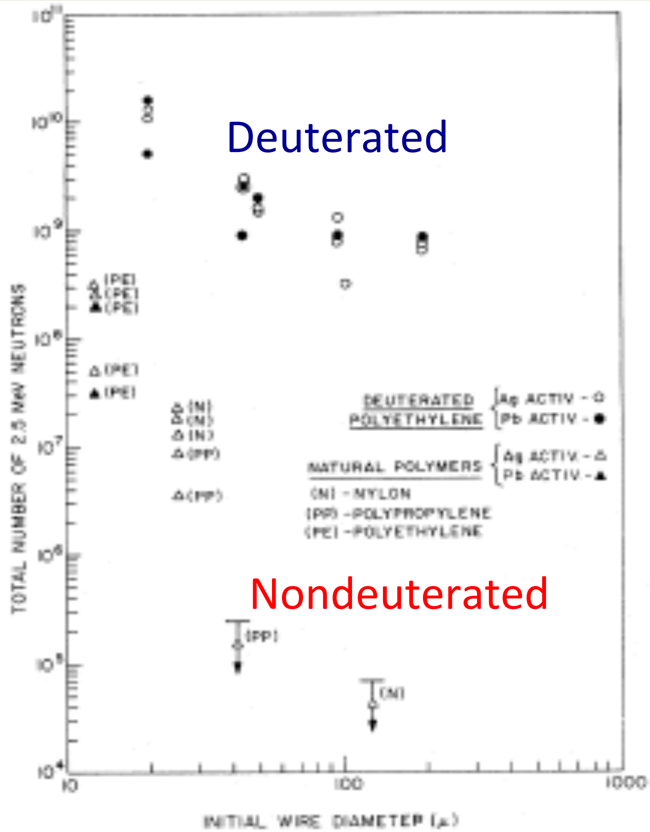



FIG. 1. Variation of neutron yield with initial fiber diameter.

The expectations about fusion from the strong interaction branch were verified on deuterated fibers.

But something extraordinary was seen:

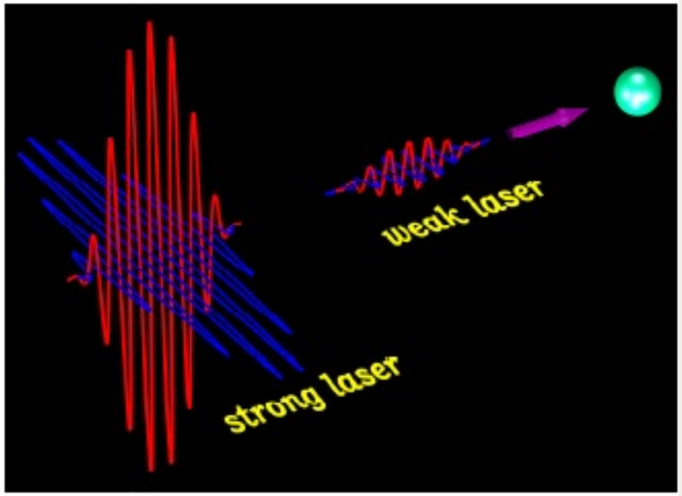
The experiments were also done with normal [nondeuterated] fibers, the yield of neutrons turned out to be 4-5 orders of magnitude higher than expected.

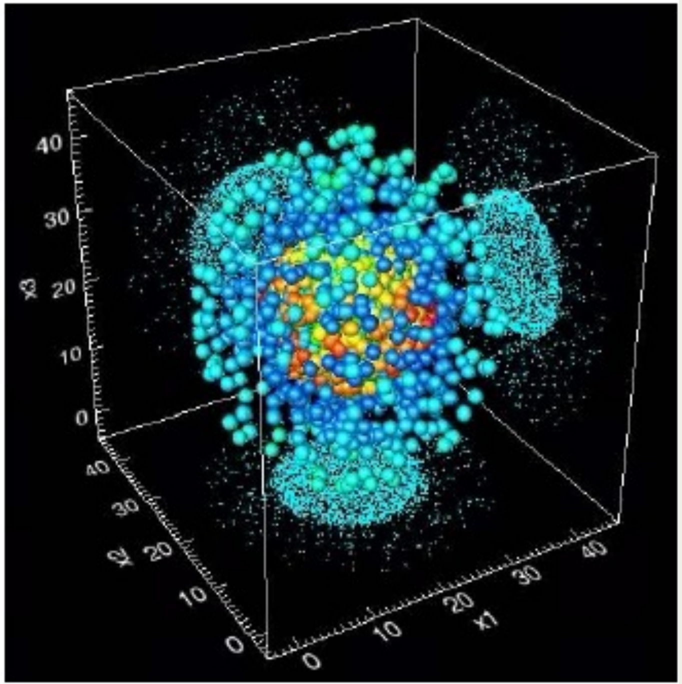
Since in normal wires there are only electrons and protons, we suggested that neutron production is via weak interactions through the collective Darwin term.

**Our explanation works quite well**

$$W_{electric} + (N+1)e^- + p \to n + Ne^-$$

# Electric LENT I



- **In recent experiments, an exploding molecular cluster of deuterium atoms is produced: a *weak LASER pulse* hits the cluster internally *ionizing the atoms within the cluster* which is followed by a *strong LASER pulse* *photo-ejecting a large number of electrons completely out of molecular cluster*. This leaves the cluster with positive charge *Ne* sufficiently large to explode.**

$$V = \frac{Q}{R} = \frac{Ne}{R}$$

$$E = \frac{Q}{R^2} = \frac{Ne}{R^2}$$

$$P = \frac{E^2}{8\pi} = \frac{N^2 e^2}{8\pi R^4}$$

# Electric LENT II

**The *tensile strength* of a material $P_c$ is defined as the maximum allowed stress before the material disintegrates.**

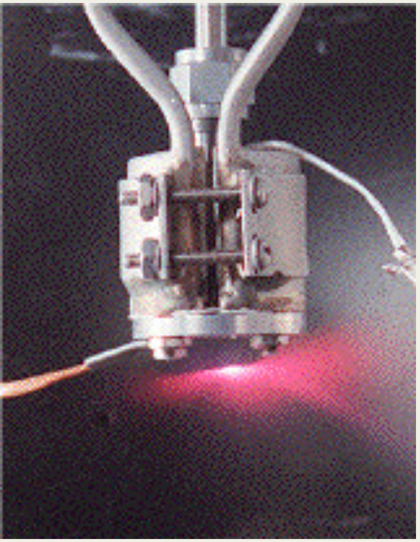
**Typical explosion fields are of the order of $eE_c \sim$ GeV/cm**

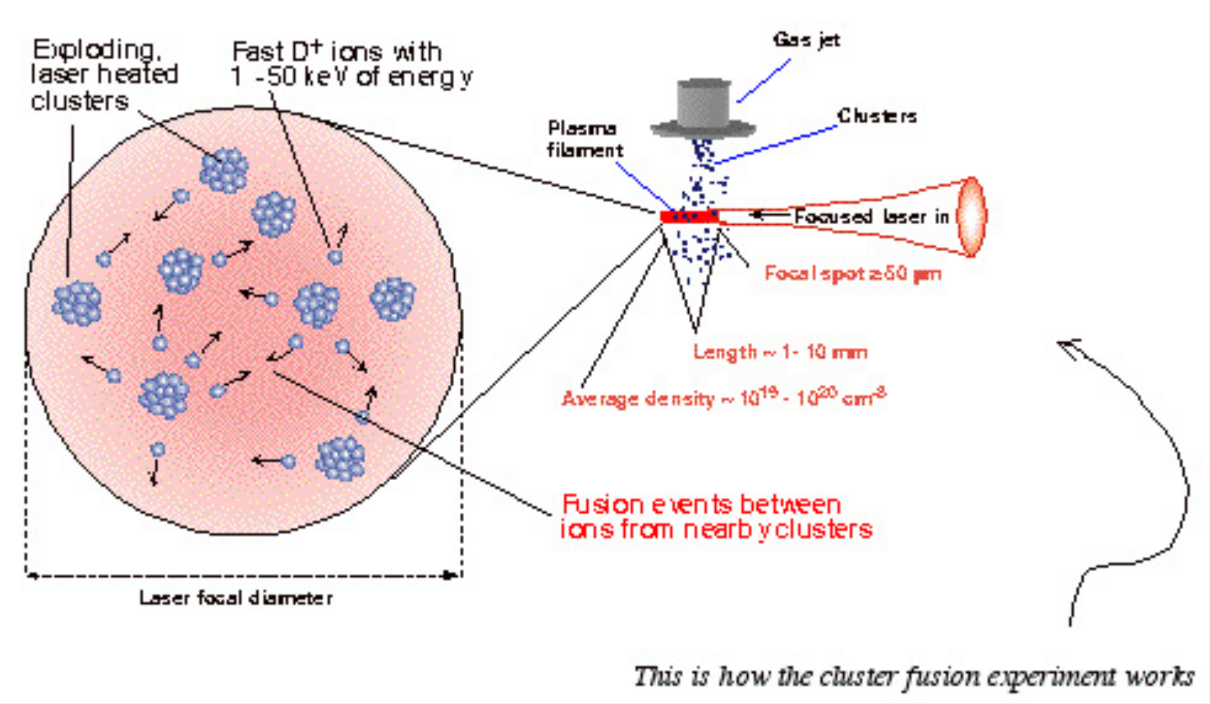
$$E_c = \sqrt{8\pi P_c}$$

$$E < E_c \Rightarrow \text{(stable)}$$

$$E > E_c \Rightarrow \text{(unstable)}$$

$$Ne = RV_c = R^2\sqrt{8\pi P_c}$$





# Electric LENT III

VOLUME 84, NUMBER 12 PHYSICAL REVIEW LETTERS 20 MARCH 2000

**Nuclear Fusion Driven by Coulomb Explosions of Large Deuterium Clusters**

J. Zweiback[1], R. A. Smith[2], T. E. Cowan[1], G. Hays[1], K. B. Wharton[1], V. P. Yanovsky[1], and T. Ditmire[1],

1. *Lawrence Livermore National Laboratory, P.O. Box 808, L-477, Livermore, California 94550*
2. *Blackett Laboratory, Imperial College of Science, Technology, and Medicine, London, United Kingdom SW7 2BZ*

(Received 14 December 1999)

**With two deuterons coming from different clusters, J. Zweiback et. al. observe the fusion reaction by detecting the neutron.**

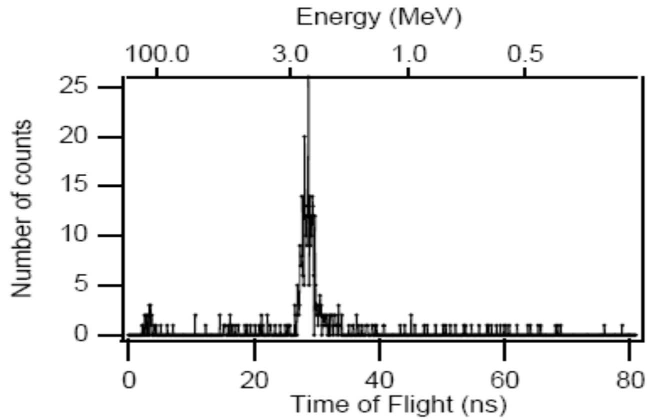



FIG. 1. Neutron time-of-flight spectrum. Neutrons were detected 62 cm from the target using a 7 mm thick plastic scintillator. The peak occurs at 2.45 ± 0.2 MeV, characteristic of DD fusion.

$${}_{1}^{2}H + {}_{1}^{2}H \rightarrow {}_{2}^{3}He + {}_{0}^{1}n$$

# Electro-Weak LENT I

There are essentially three options for accelerating electrons which have produced good results:

1. Fast Lasers: Very fast femtosecond lasers have been used to construct table top electron accelerators [Beam energy 100 MeV- 1 GeV]
2. Magnetic Means: An excellent example of EW LENT via magnetic field in Nature is provided by the acceleration of electrons and protons in the Solar Corona.
3. Electric Means: A laboratory example of an electric field acceleration of electrons is provided when piezoelectric rocks are crushed or when pyroelectric crystals are heated/cooled.

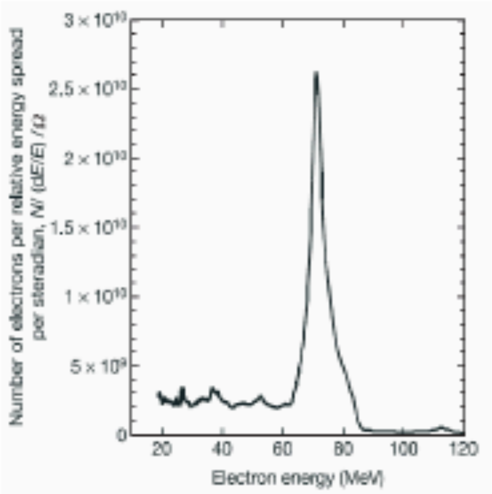
# DREAM BEAMS by FAST LASERS I

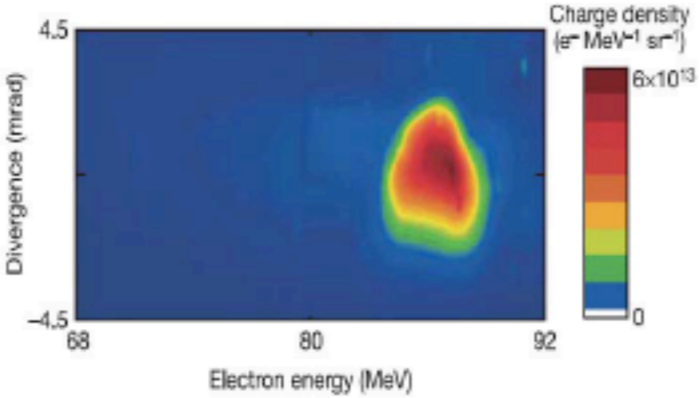
## 2nd Session – Experiments performed Multi-TW table top laser systems – Recent historical landmarks – First Mono-Energetic LWFA experiments

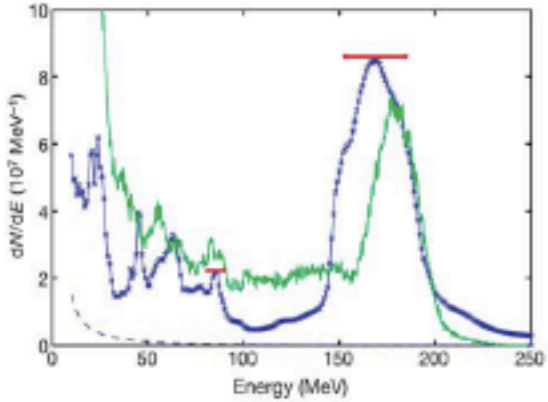
**Mangles et al, Imperial College, UK: 70 MeV beam**

**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*

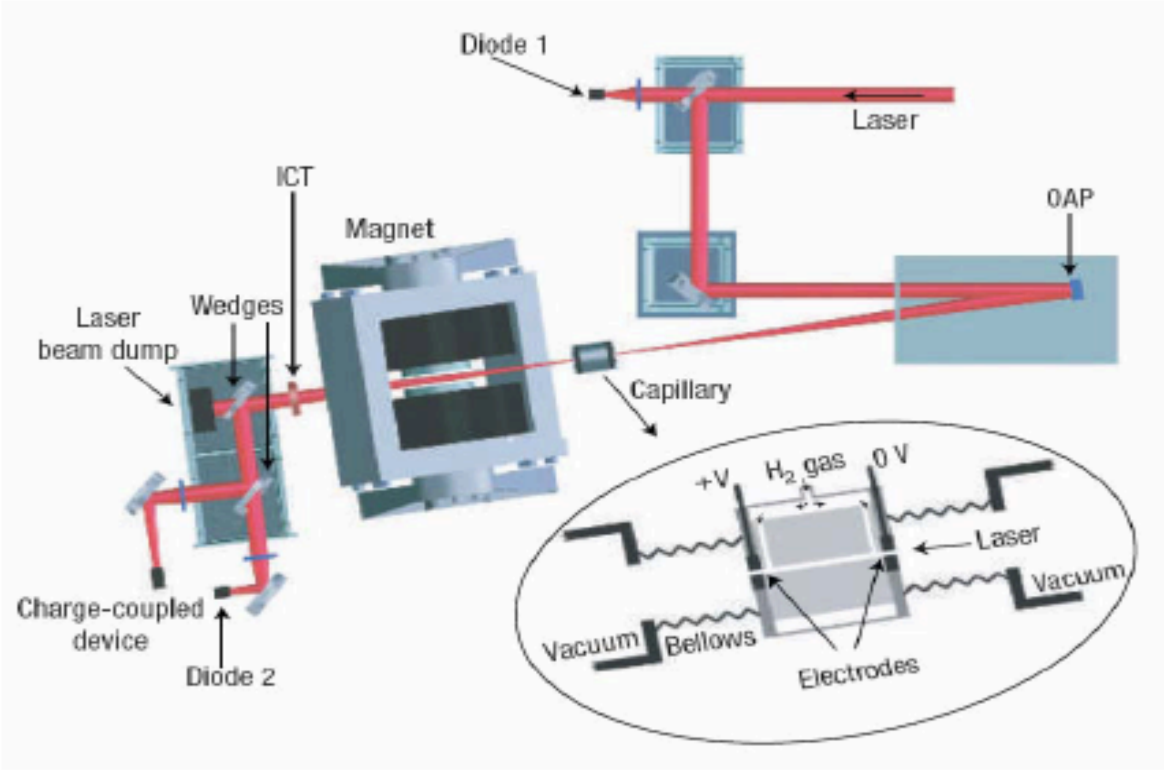
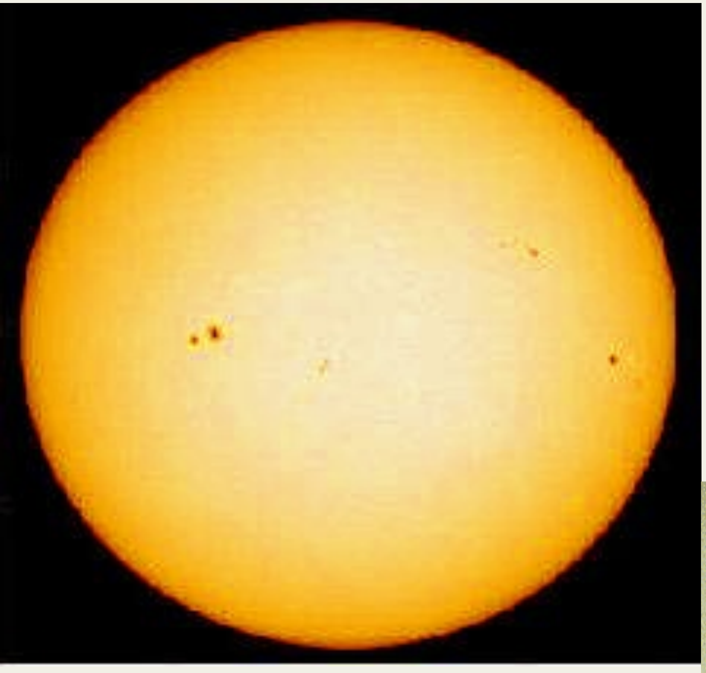
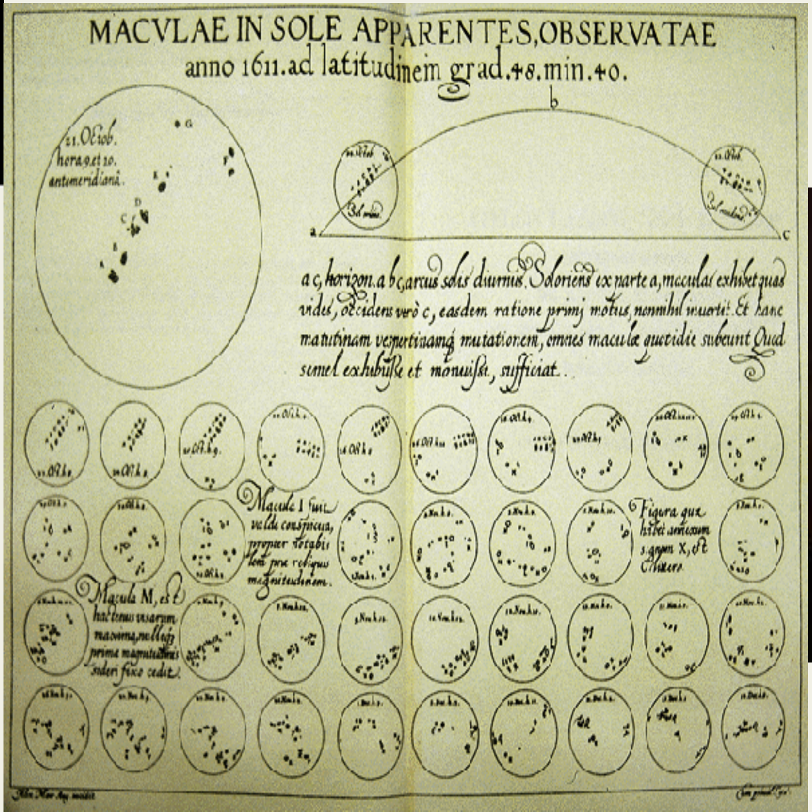



Image taken from Leemans et al., Nature Physics, 2 (2006)

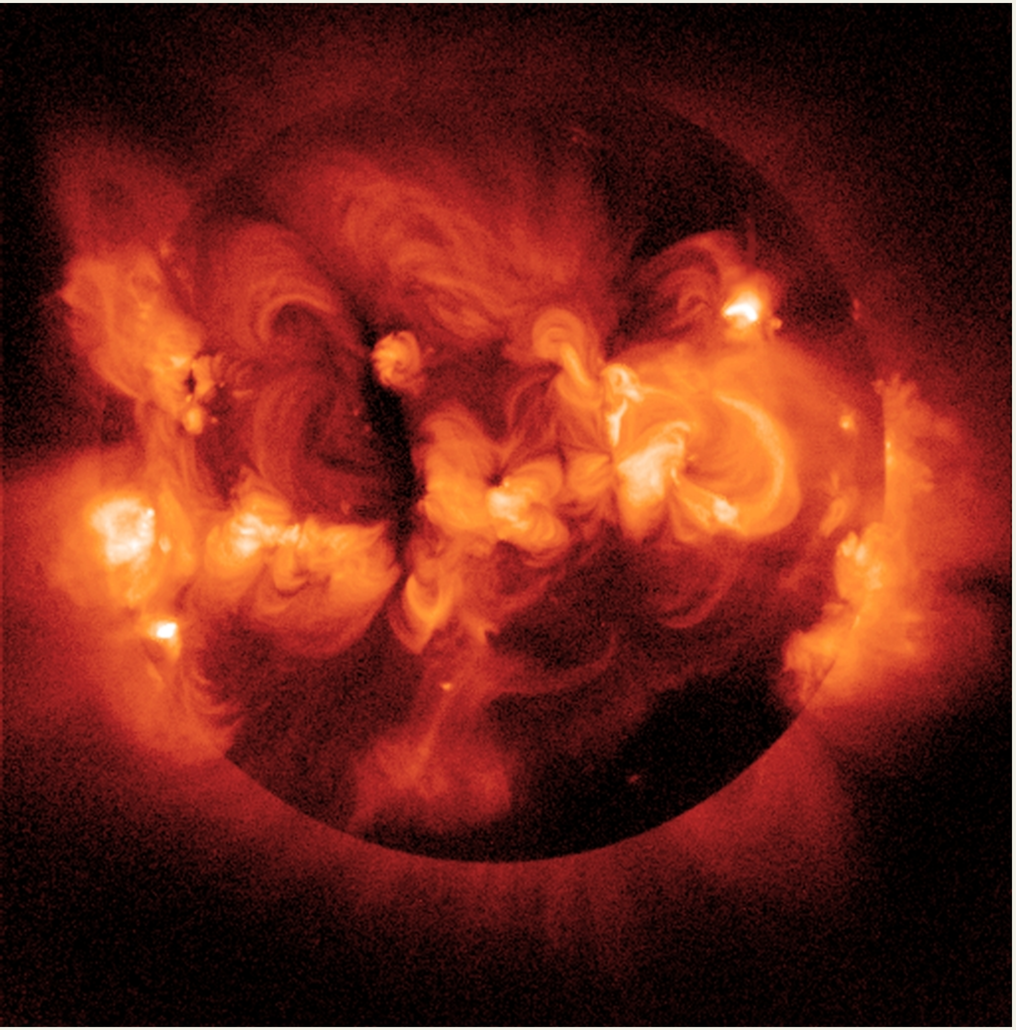
# Solar Surface I



**Picture of the sun taken with an optical camera. There is little surface structure beyond a few dark “sunspots”**



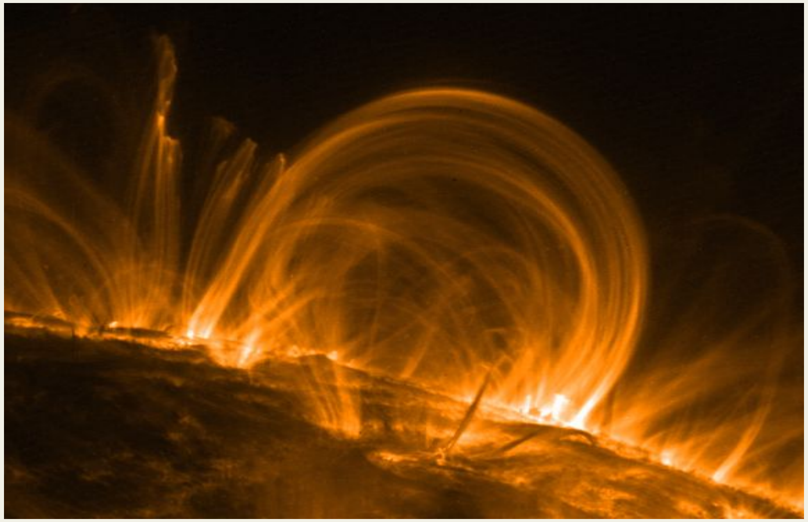

# Solar surface II & Solar Corona

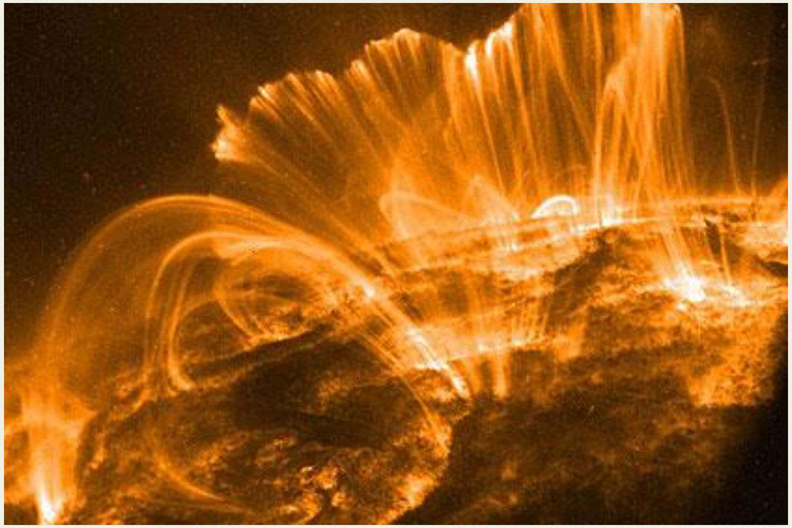


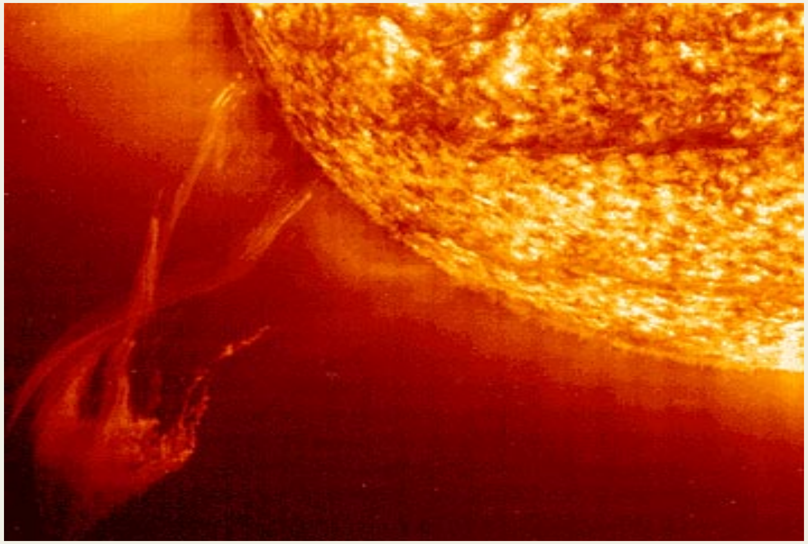
←UV & X-ray pictures

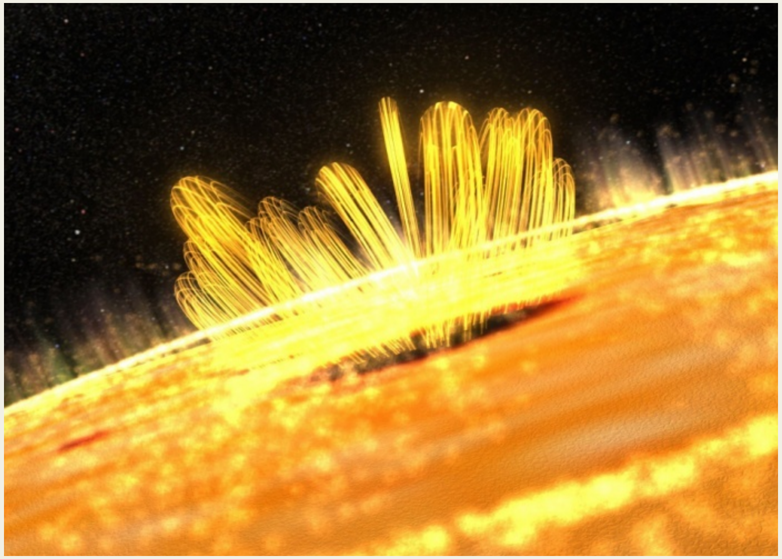
# Magnetic Flux Tubes

Exit from one sunspot to dive into another

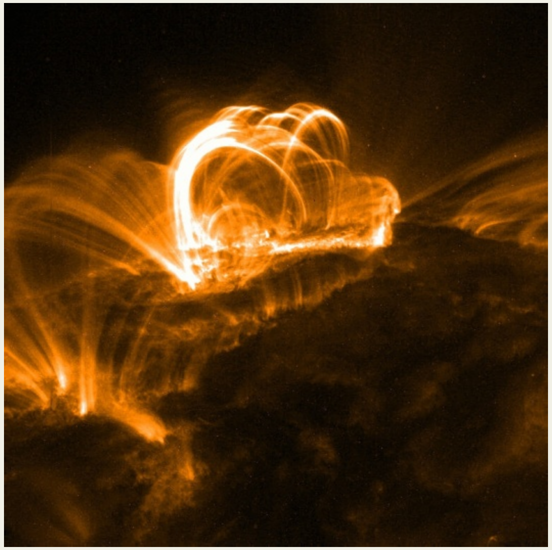


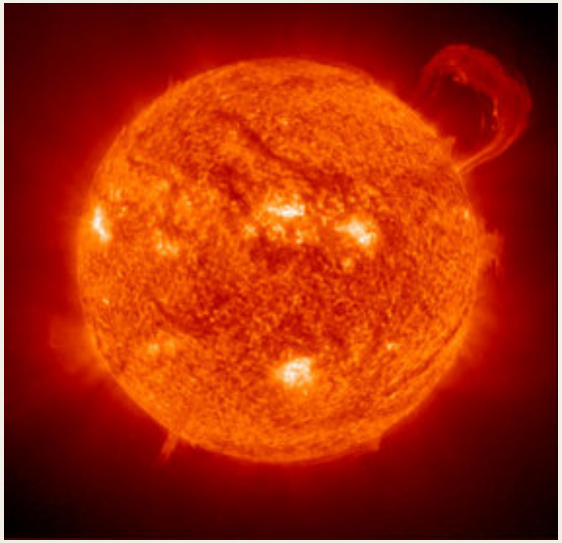






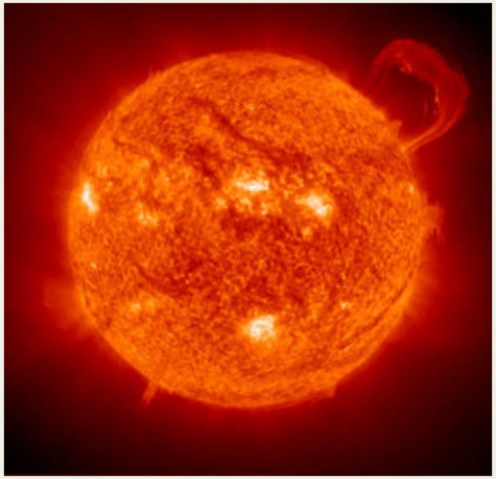
# Magnetic Flux Tubes II

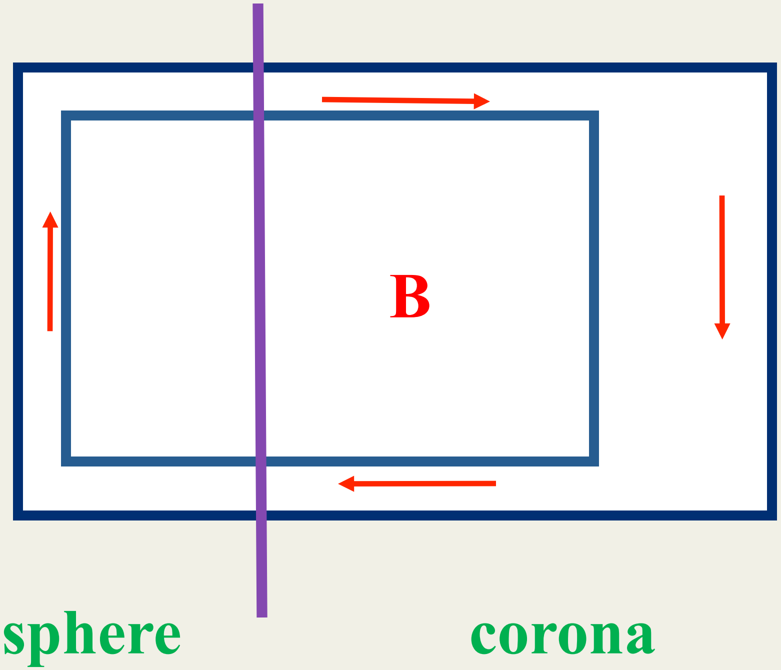


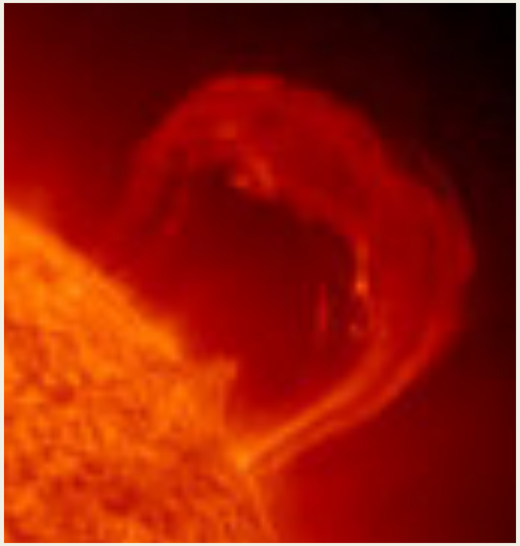


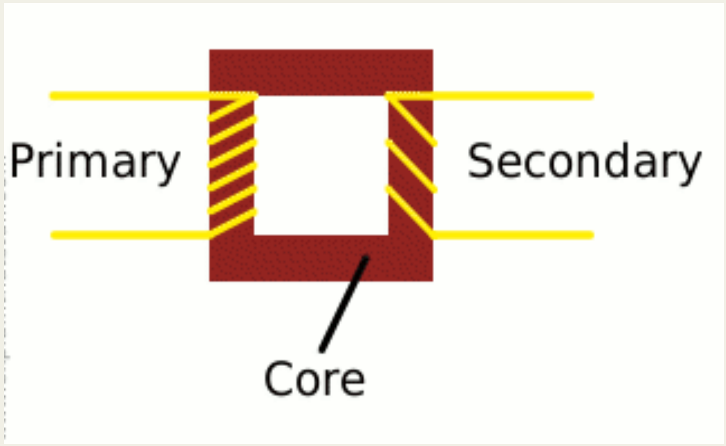
**Once in a while magnetic flux tubes break.**
**Giant Flares from Exploding Flux Tubes**
**Producing huge amounts of energy. HOW?**

# Magnetic Flux Tubes III

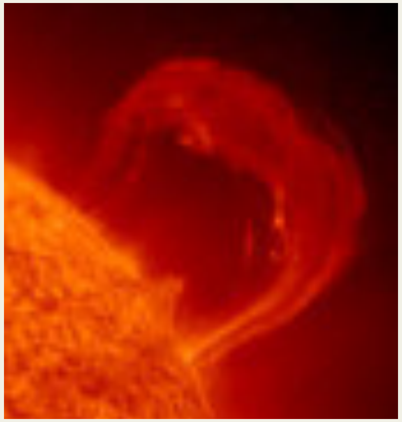






# Solar Flares I



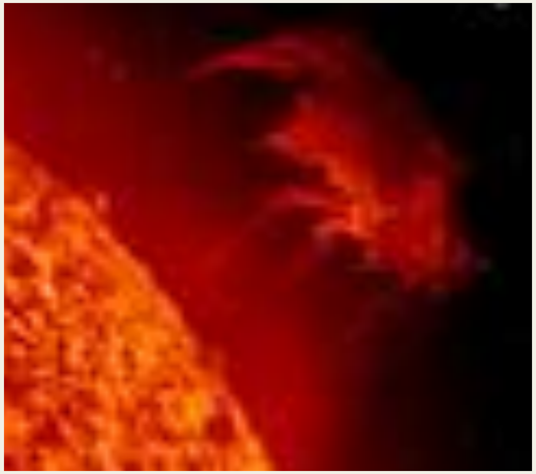
$$e\overline{V} \approx 30\,\mathrm{GeV}\left(\frac{\mathrm{B}}{\mathrm{kiloGauss}}\right)\left(\frac{\pi\,\mathrm{R}}{\mathrm{c}\Delta\,\mathrm{t}}\right)\left(\frac{\mathrm{R}}{\mathrm{kilomoter}}\right)$$

$$B \sim 1\,\mathrm{kiloGauss}$$

$$\Delta\mathrm{t} \sim 10^2\ \mathrm{sec}$$

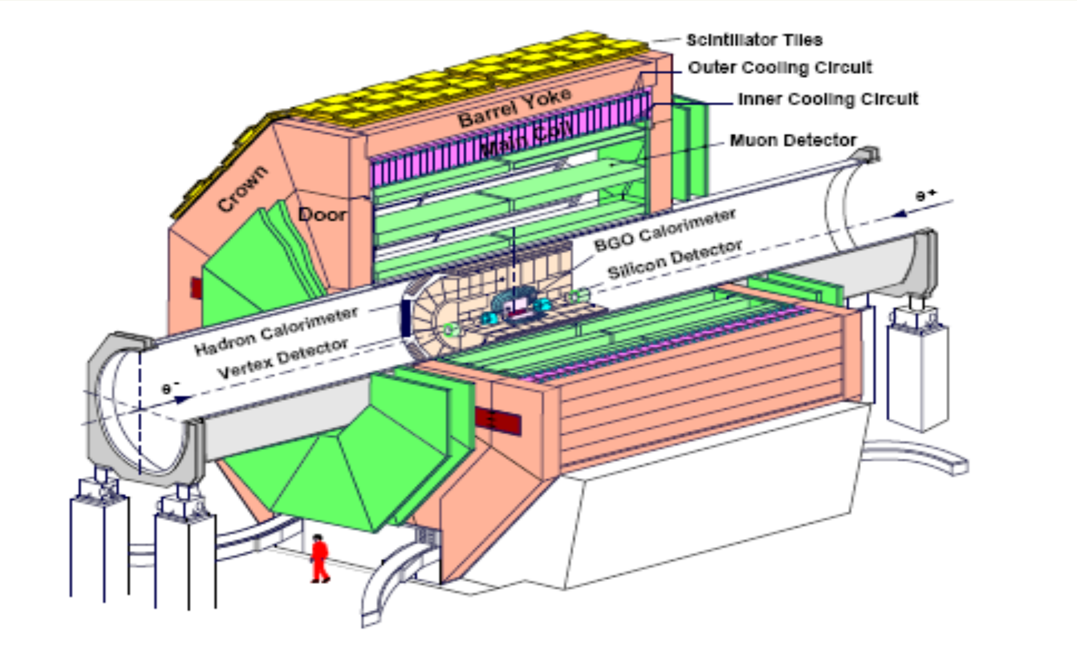
$$R \sim 10^4\ \mathrm{kilomoter}$$

$$e\overline{V} \sim 300\ \mathrm{GeV}$$



**Faraday Law**
**Betatron 300 GeV**
**electron – proton collider**

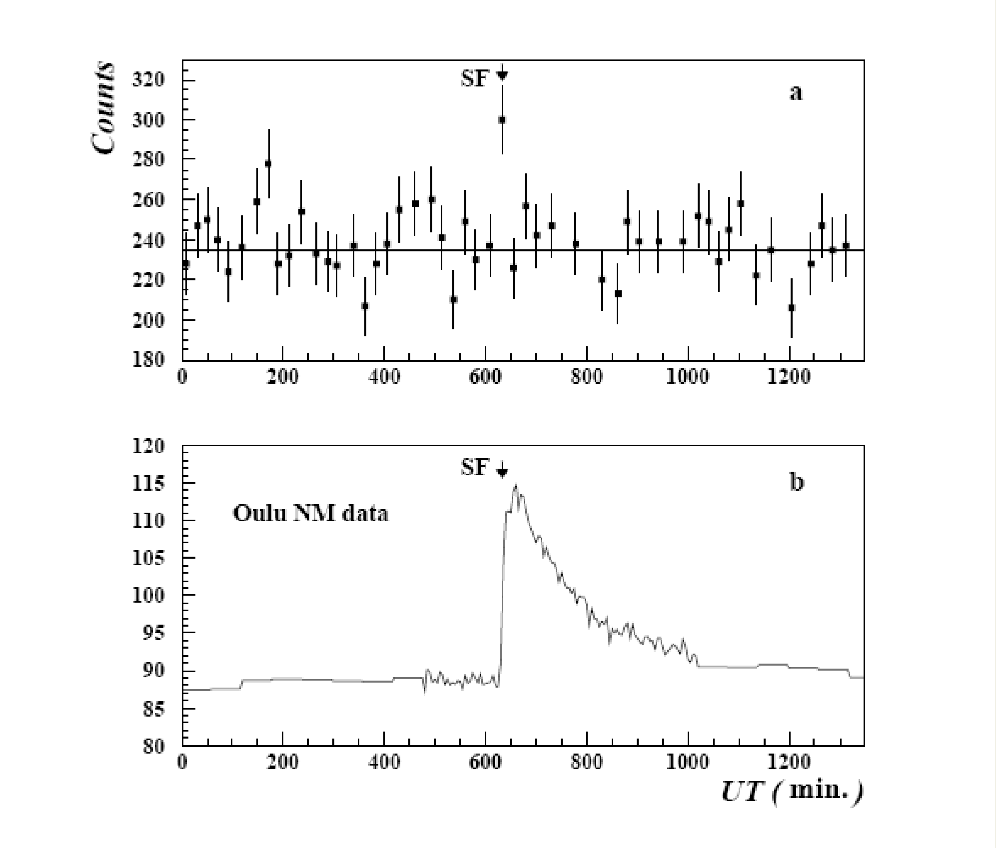
# Solar Flares II




**Only the muon detectors, the magnet and the scintillator tiles were used in the LEP (*L3+C Collaboration*) solar flare experiment of July 14, 2000.**

# Solar Flares III

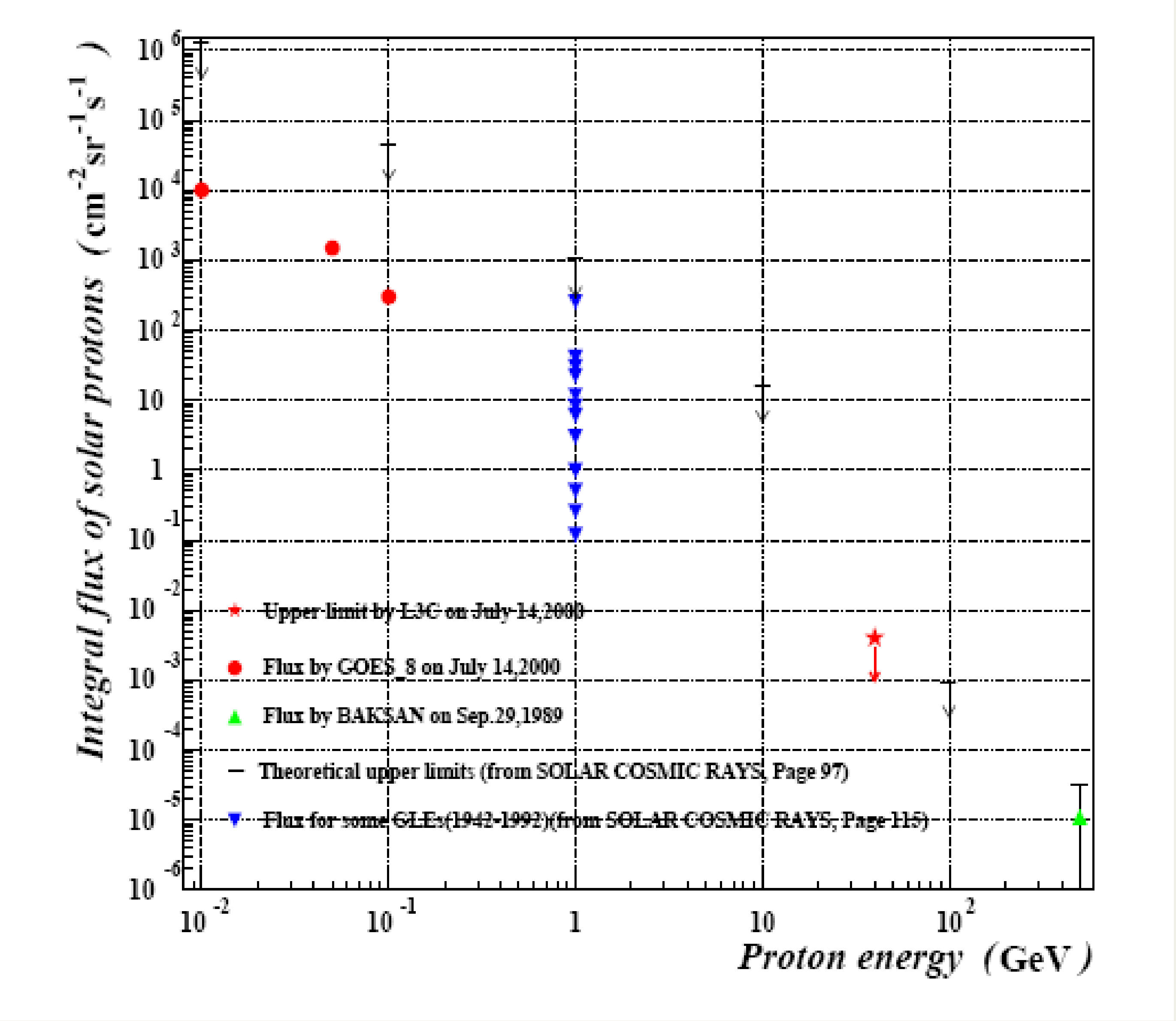
The time when the peak occurred at CERN in Geneva(TOP) matches exactly as to when neutron monitors (NM) at Oulu (Below) saw peak in their signals from the Solar Flare (SF).



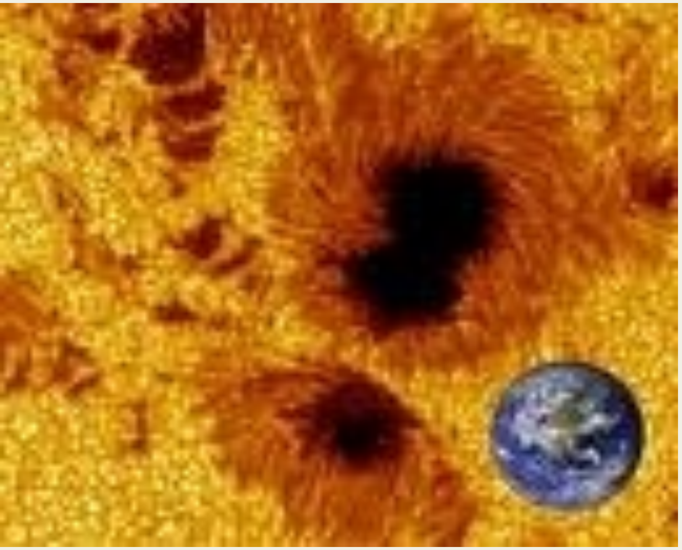

**Number of events as a function of time in minutes for the whole day (14th July 2000) in sky cell No.37. The solar flare time is 10:30 UT is marked by `SF'. The live-time bin width is 16.78 minutes. The solid line shows the mean value of the background.**

# Solar Flares IV

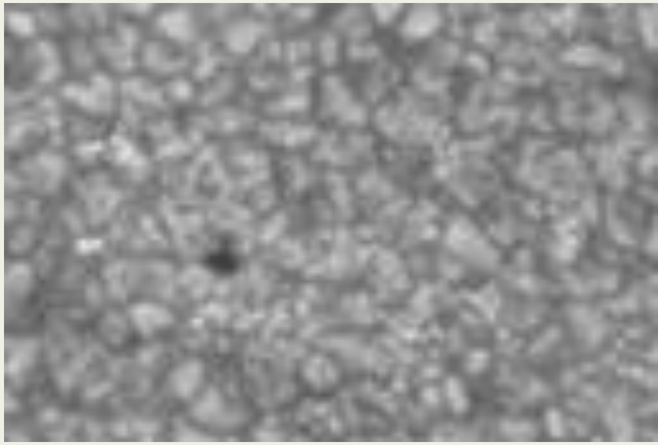
Low energy protons (shown on the left by red dots) are from the core of the Sun. High energy protons on the right are from giant Solar flares

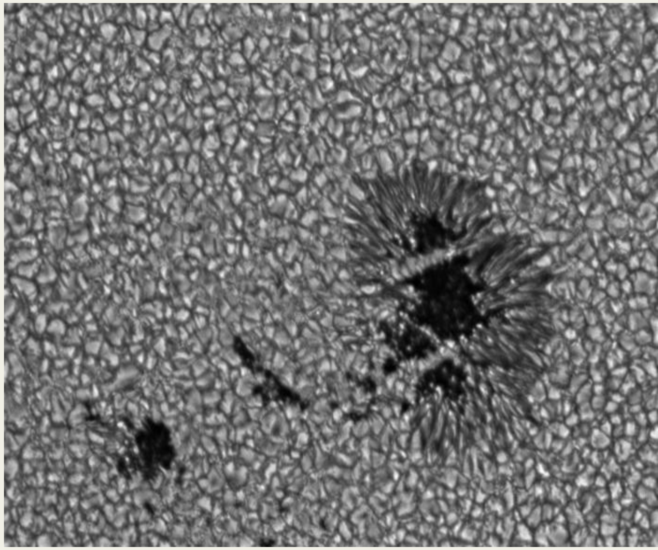


# Solar Carpet I



On the Solar surface there is a tapestry of entwined magnetic field with complicated patterns called the Solar Carpet.





# Solar Carpet II: Single Threaded Coils

## Weak interactions on a single threaded coil:

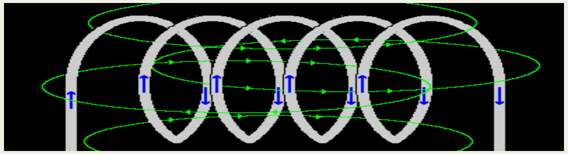
$$W_{magnetic} + e^- + p^+ \rightarrow n + \nu_e$$

$$\delta W = \frac{1}{c}\Phi\,\delta I$$

$$eB = 29.9792458\left(\frac{B}{\text{kiloGauss}}\right)\left(\frac{\text{GeV}}{\text{kilometer}}\right)$$

$$\delta I = \left(\frac{\text{ev}}{L}\right)$$

$$W_{magnetic} = \left(\frac{e\Phi}{L}\right)\frac{\text{v}}{c}$$



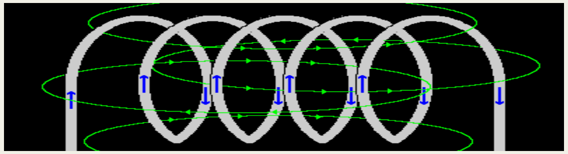
$$W_{magnetic} = eB\left(\frac{\Delta S}{L}\right)\frac{\text{v}}{c}$$

$$W_{magnetic} = eB\left(\frac{\pi R^2}{2\pi R}\right)\frac{\text{v}}{c}$$

$$W_{magnetic} \approx (15\,\text{GeV})\left(\frac{B}{\text{kiloGauss}}\right)\left(\frac{R}{\text{kilometers}}\right)\frac{\text{v}}{c}$$

$$W_{magnetic} = eB\left(\frac{R}{2}\right)\frac{\text{v}}{c}$$

# Single Threaded Coils II

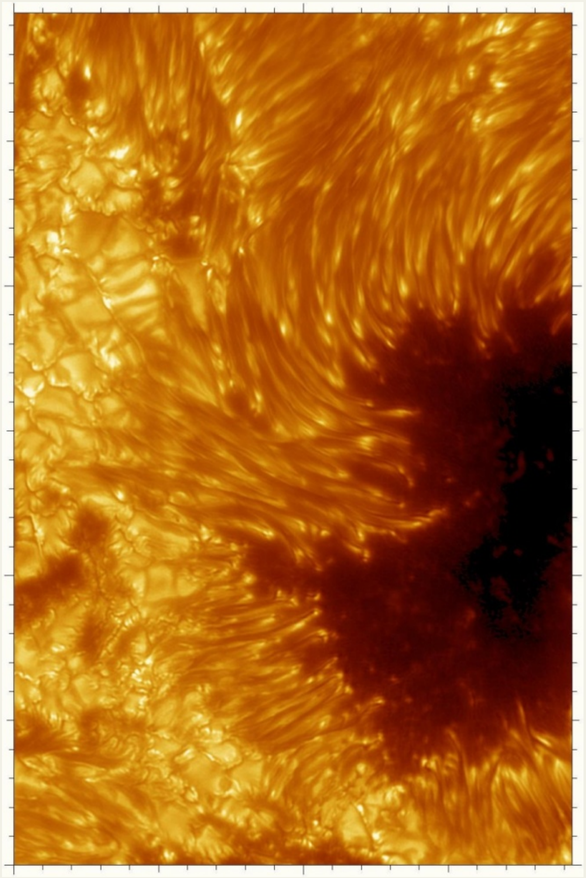


$$W_{magnetic} \approx (15\,\mathrm{GeV})\left(\frac{B}{\mathrm{kiloGauss}}\right)\left(\frac{R}{\mathrm{kilometers}}\right)\frac{\mathrm{v}}{c}$$

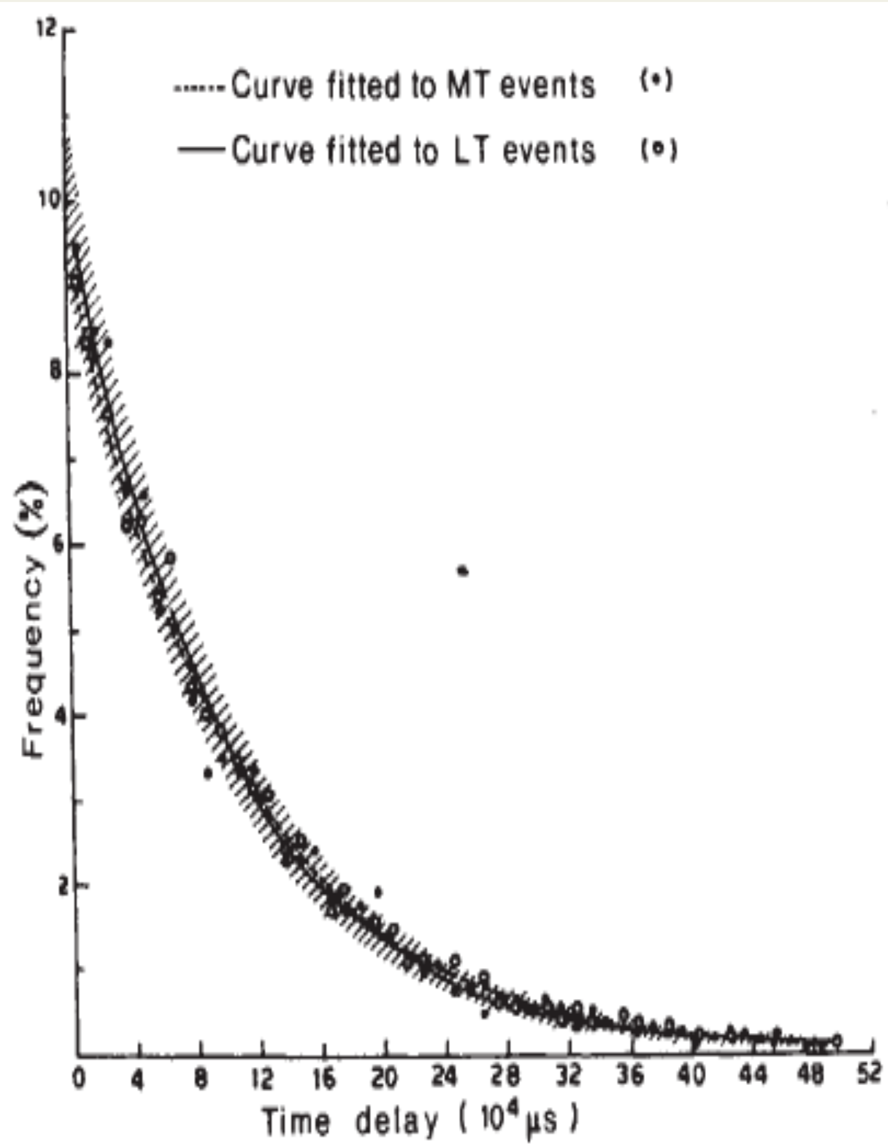
$$B \sim 1\,\mathrm{kiloGauss} \quad R \sim 10^2\,\mathrm{kilometers} \quad \frac{\mathrm{v}}{c} \sim 10^{-2}$$

$$\mathbf{W_{magnetic} \sim 15\ GeV}$$

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



# 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**

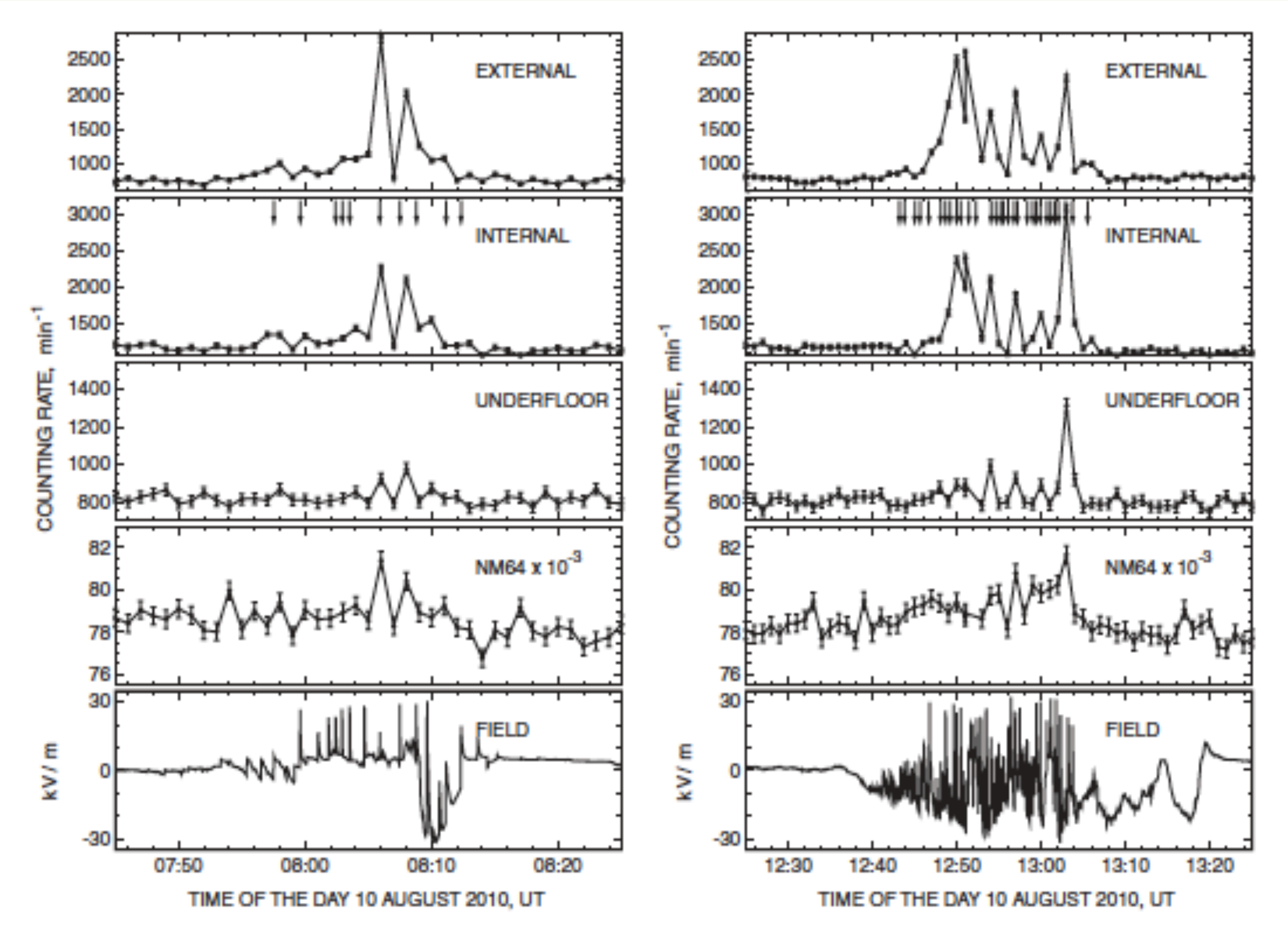
Bhabha Atomic Research Centre, Nuclear Research Laboratory, Zakura, Naseem Bagh, Srinagar-19006, Kashmir, India


Mean Current about 35 Kilo Amperes

$(I/I_o) \sim 2$

# 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/ $cm^2$ /sec. is needed to obtain the observed neutron flux.
- The obtained $\gamma$- ray emission flux was about 0.04 quanta/ $cm^2$ /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]: arXiv 1109.4911

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.

# Fusors

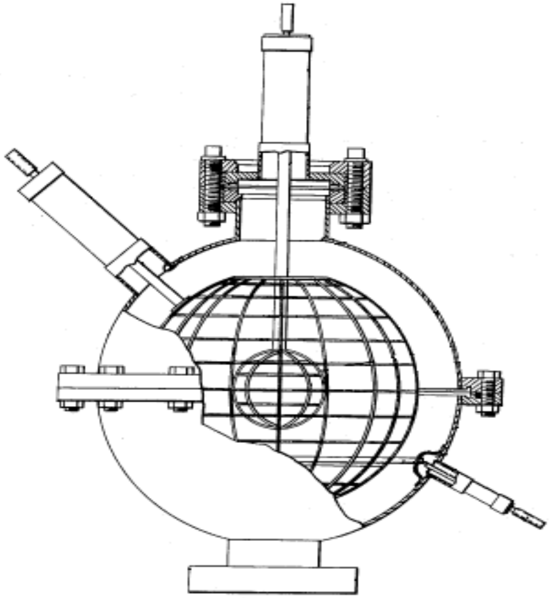
In 1964, P. T. Farnsworth [the inventor of TV video camera tube] created d-d and later d-t fusion leading to neutron production, through inertial electrostatic confinement using modest electrostatic fields.

A potential difference of 80 Kilo Volts in commercial devices, accelerates deuterons with energies up to 15 KeV so that fusion occurs with the release of neutrons..

This is not a speculative idea but rather a mature technology.

Table top devices can be purchased which can produce more than several million neutrons per second.

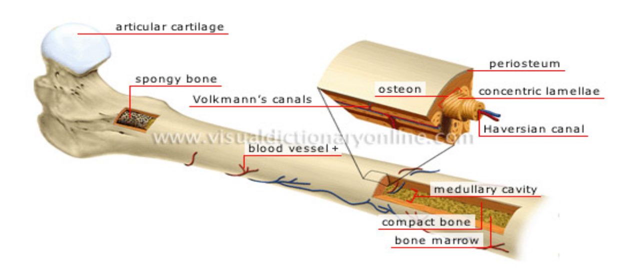
A quick internet search will reveal that fusors are a popular science fair projects built by students.



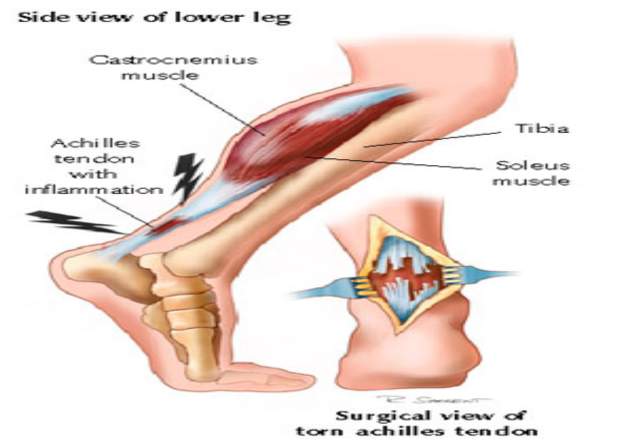
# LENT in Smart Materials I: Pyroelectrics

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.



# Neutron production from fracturing rocks [WSS]: II

Examples of piezoelectrics: Bone, hair, quartz

| | |
|---|---|
| $\mathcal{E}$ | Electric field |
| $w$ | Strain tensor |
| $\beta$ | Piezoelectric constant |

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

Neutron Production from the Fracture of Piezoelectric Rocks

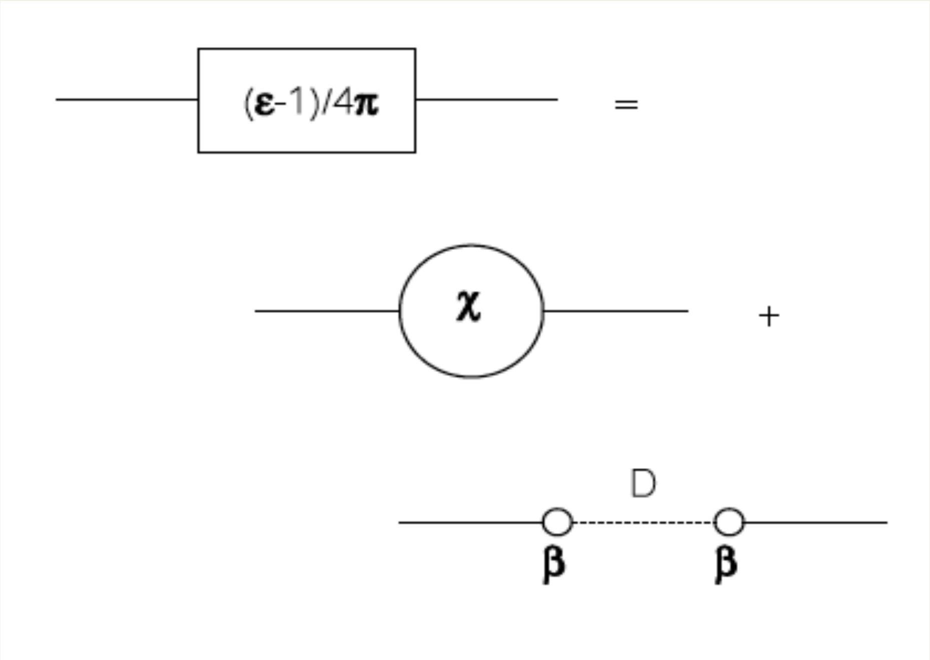
[YS, A. Widom & J Swain: J. Phys. G: Nucl. Part. Phys. 40 (2013) 015006]

# Neutron production from fracturing rocks [WSS]: III

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

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

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




- $D_{ijkl}$ is the phonon propagator
- $\varepsilon_{ij}$ 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 $\beta_{ijk}$
- 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) $v_s$ velocity of sound vs. c is ~ $10^{-5}$ hence

$(\omega_{phonon}/\omega_{photon})$ ~ $10^{-5}$ for similar sized cavities

(ii) The mean electric field E ~ $10^5$ Gauss

(iii) The frequency of a sound wave is in the microwave range $\Omega \sim 3 \times 10^{10}$/sec.

(iv) The mean electron energy on the surface of a micro-crack under stress $\sigma_F$ is about W ~ 15 MeV

(v) The production rate of neutrons for the above is

$$\Gamma(e^- + p^+ \to n + \nu_e) \sim 0.6 \text{ Hz}$$

$$\varpi_2 \sim 10^{15} \frac{\text{Hz}}{\text{cm}^2} .$$

# Conclusions:

Overwhelming experimental evidence and sound theoretical arguments now exist that all four fundamental interactions lead to LENT both in Nature and in the laboratory.

If before you were only convinced, now you can feel certain.

Hence, it is time to assemble and use modern technology to achieve further sorely needed applications of the Standard Model of Particle Physics.

We must in the words of T. S. Eliot – a consumate academician himself- stop indulging in

*"a tedious argument of insidious intent"*

Thank you
for your attention
and
your patience

# Extra Slides

Neutron Production from *Smart* materials:
Pyro and Piezo electrics

# LENT: Low Energy Nuclear Transmutations From specially prepared materials

By

Yogendra Srivastava
INFN & University of Perugia, Perugia, Italia

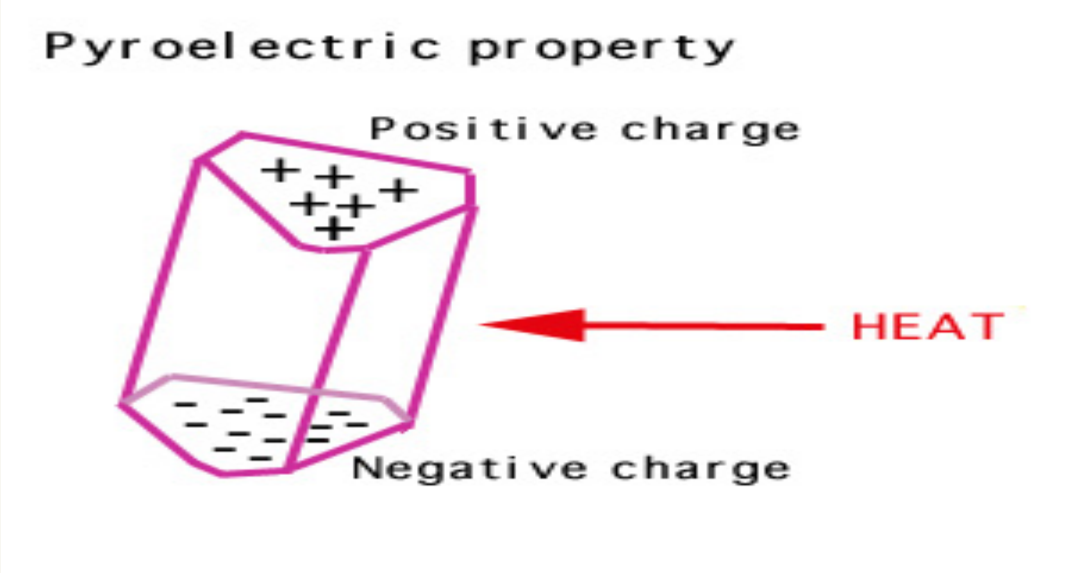
December 14, 2012

@

Casa dell' Aviatore, Roma

# Contents of the Talk: I

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




2. Piezoelectric crystals
when crushed produce
electric fields

# LENT in Smart Materials I: Pyroelectrics

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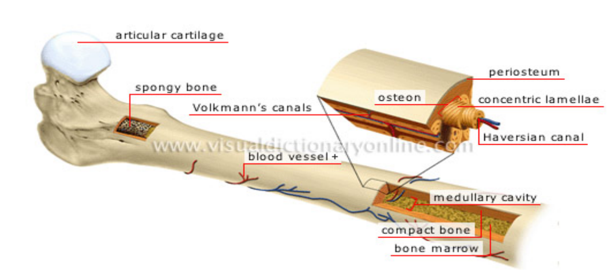
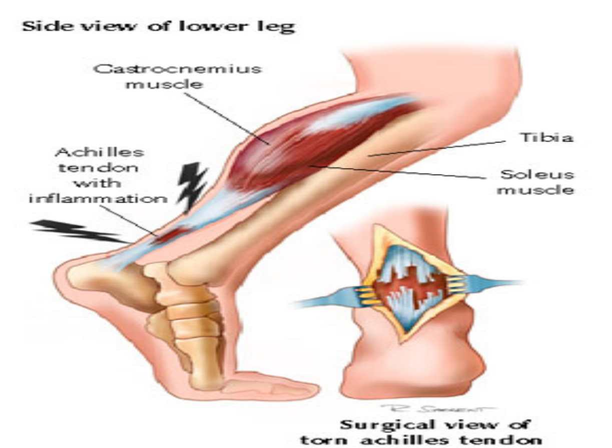



It was experimentally shown that pyroelectric crystals when heated or cooled produced nuclear dd fusion evidenced by the signal of 2.5 MeV neutrons. The system was used to ionize the gas and accelerate the ions up to 200 KeV sufficient to cause dd fusion. The measured yields agree with the calculated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



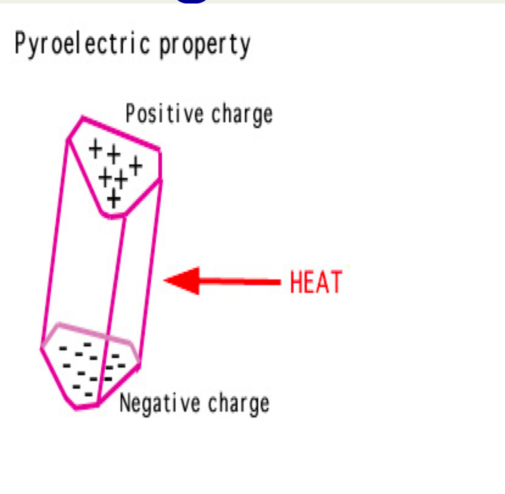
# Pyroelectrics II

- 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 ($E_{eff}$) generated in the crystal is assumed proportional to the change in the temperature ($\Delta T$): $E_{eff} = \phi \, \Delta T$
- Lithium Tantalate [$LiTaO_3$] 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; $\varepsilon$ 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

$$2\ eV = 933\ KeV$$

- 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 laboratories around the world.

# Pyroelectric Fusion IV

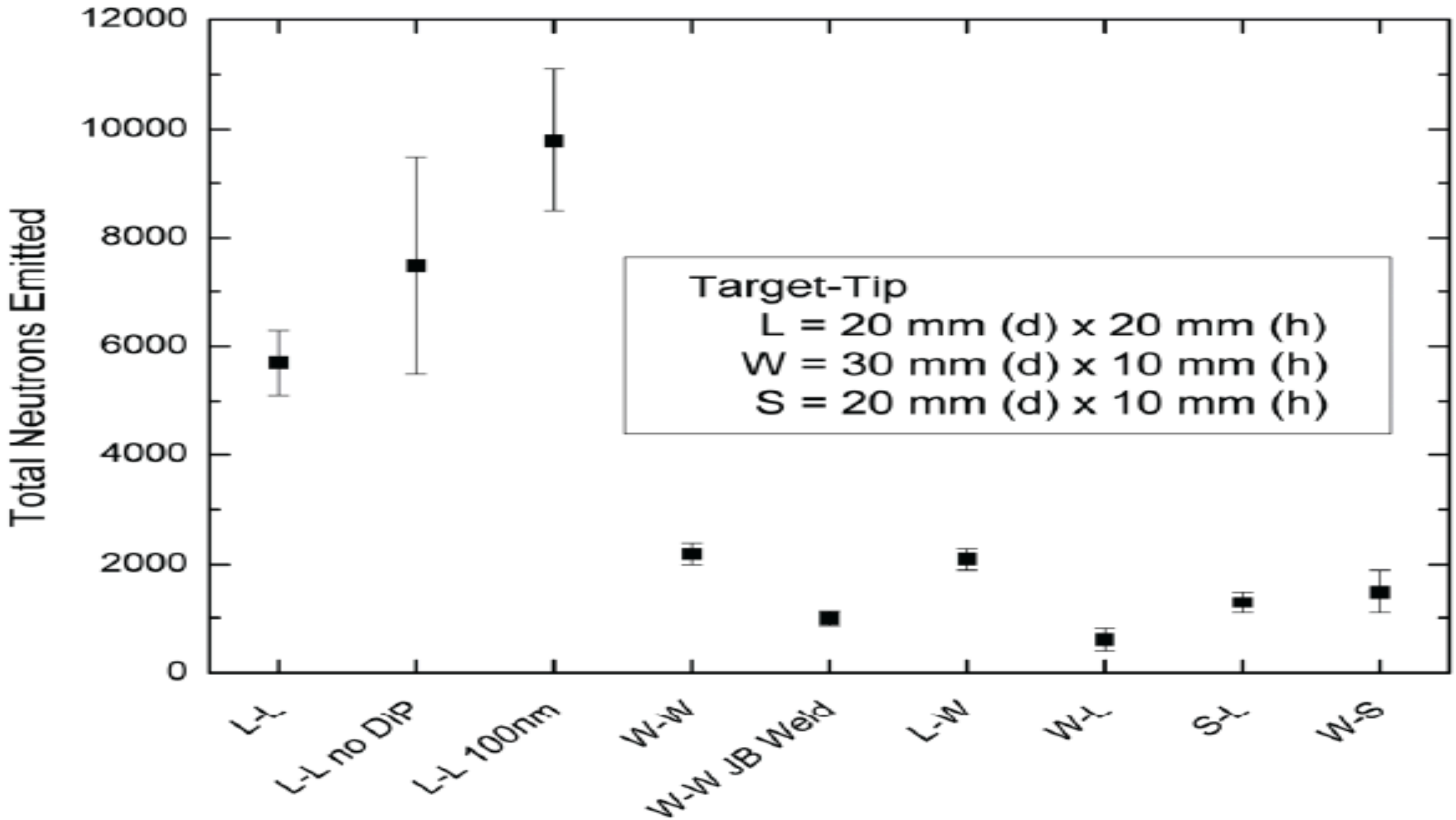



Fig. 2. Total neutrons emitted over 5 minutes after subtracting background and accounting for an absolute detection efficiency of (4.2 ± 0.3) %. Each data point represents the weighted average of three trials weighted by the statistical error with the uncertainties representing the weighted standard deviation of the counts and background counting statistics [8].

# 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 Discharge Cell II

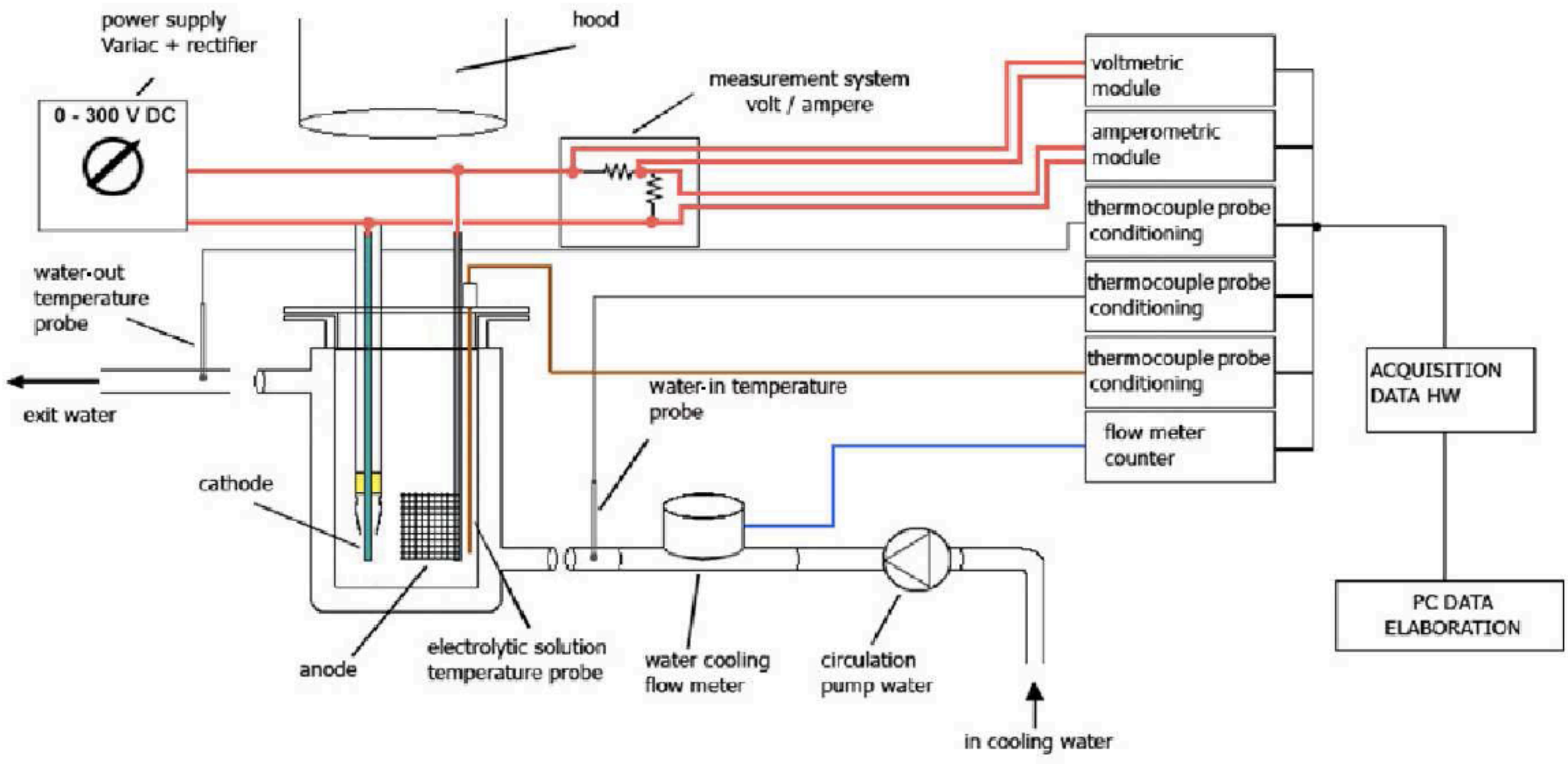



Fig.1 Experimental set-up for the generation of a plasma discharge in an electrolytic cell.

# Plasma Cell III: CR-39 Neutron Detector

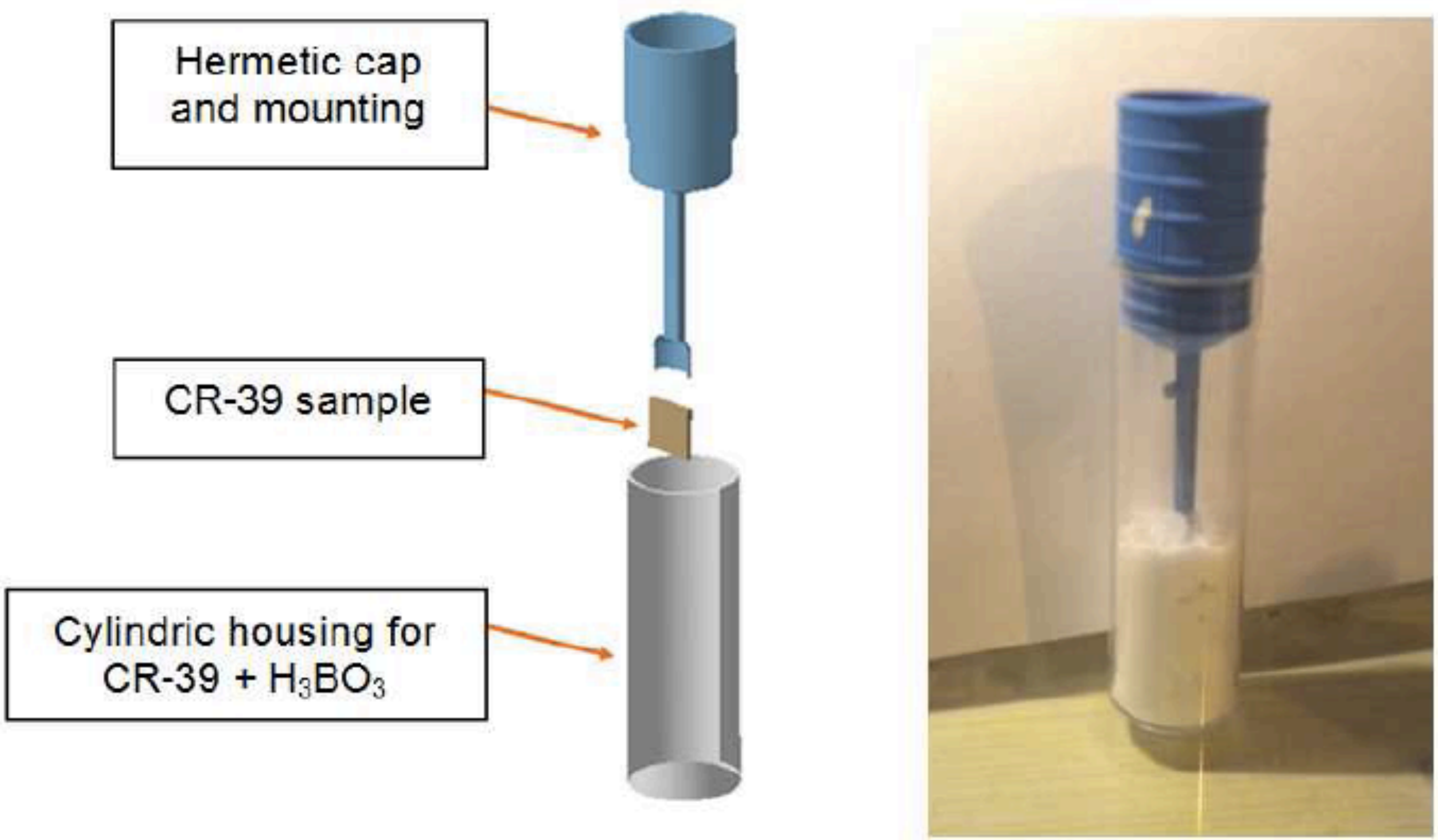
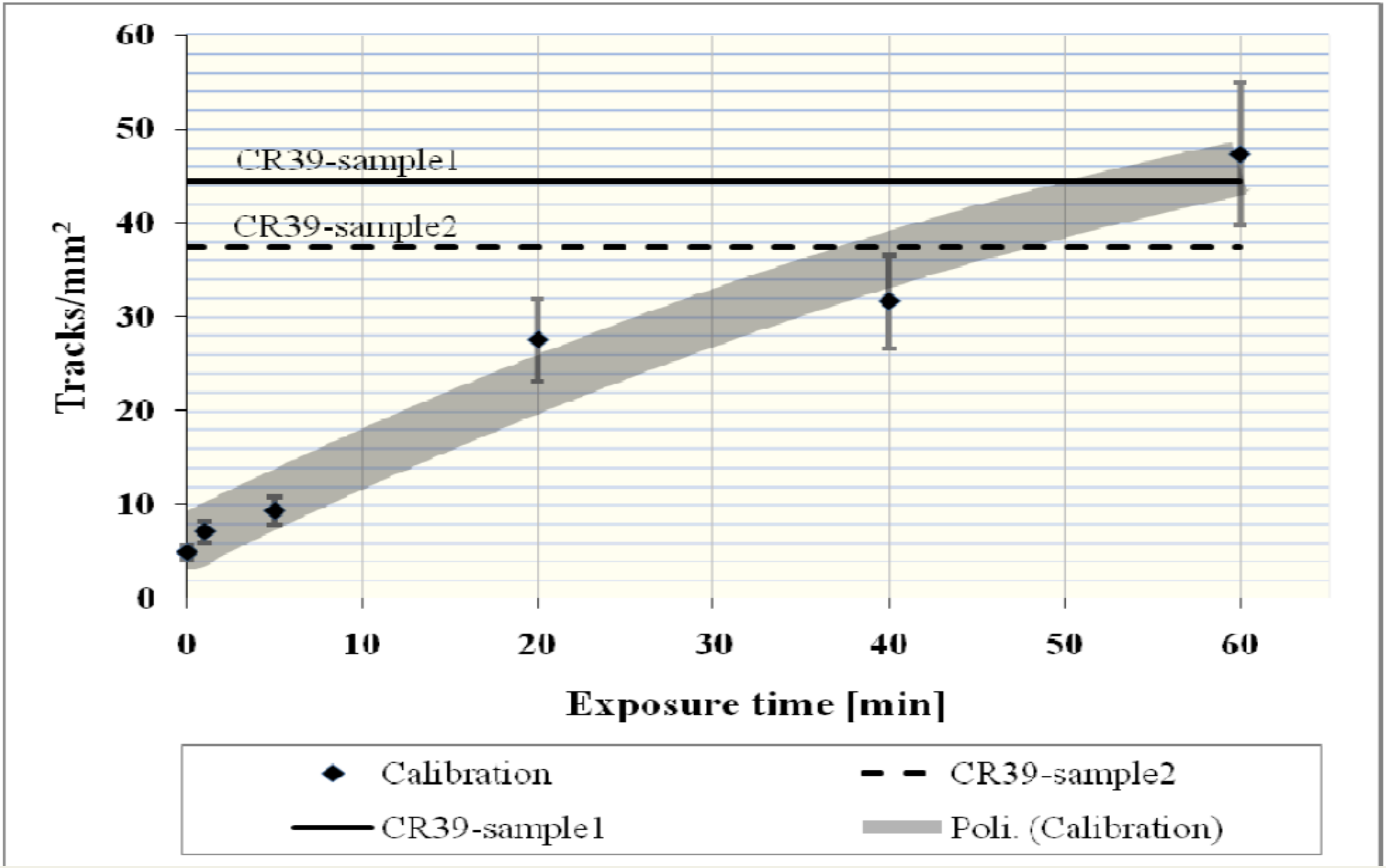



Fig. 2 Neutron detector scheme (left) and photo (right).

# Plasma Cell V: Neutron Flux



# Sternglass Experiment I

**Intense Electron Beam Dumped into Tungsten Block**
**Kinetic Energy E~50 KeV**

**Neutrons Were Produced**

# Sternglass Experiment II

- Graduate Student Brings Below Energy Threshold Neutron Production and Shows the data to H. Bethe.

- H. Bethe Contacts A. Einstein to Ask What has Happened to Relativistic Kinematics.

- Einstein Contacts Sternglass and Advises that an Important Discovery Has Been Made.

(i) Do not back down to skeptics.
(ii) Keep the electron beam intense.
(iii) Suggested quantum mechanical collective energy transfer.

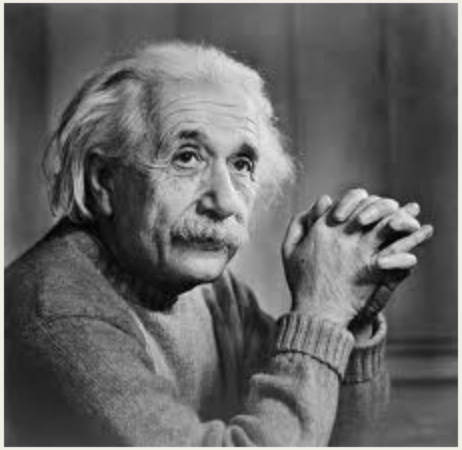
# Sternglass Experiment III
# Einstein Kinematics

## Single Electron Energy Transfer

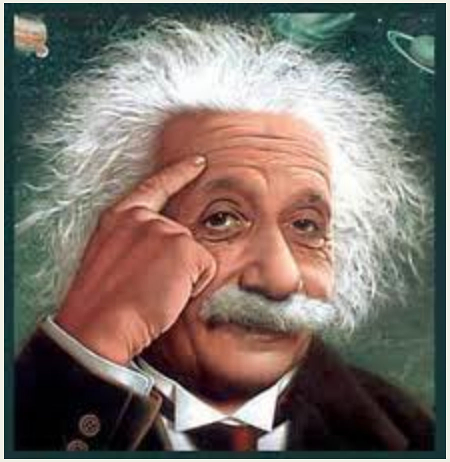
$$e^- + p^+ \to n + \nu_e$$

## Collective Electron Energy Transfer

$$(e_1^- + e_2^- + \cdots + e_N^- + e_{N+1}^-) + p^+ \to n + \nu_e + (e_1^- + e_2^- + \cdots + e_N^-)$$



# Sternglass Experiment IV



Sternglass Ignores all of Einstein's Advice.

(i) He lowers the beam intensity.
(ii) He recovers the threshold energy.
(iii) He backs down to Rutherford.

# Nuclear transmutations: I

The great Italian genius Enrico Fermi used to say

Give me enough neutrons
and I shall give you the
entire periodic table

$$n + {}^{A}X_{Z} \rightarrow {}^{A+1}X_{z}$$

$${}^{A}Y_{z} \rightarrow {}^{A}Y_{z+1} + e^{-} + \bar{\nu}_{e}$$

# A Complete Lithium Cycle

$$
\begin{aligned}
{}^6_3Li + n &\rightarrow {}^7_3Li \\
{}^7_3Li + n &\rightarrow {}^8_3Li \\
{}^8_3Li &\rightarrow {}^8_4Be + e^- + \bar{\nu}_e \\
{}^8_4Be &\rightarrow {}^4_2He + {}^4_2He.
\end{aligned}
$$

On the other hand, ${}^4_2He$ can successively absorb neutrons and, through the formation of intermediate halo nuclei, reproduce Lithium

$$
\begin{aligned}
{}^4_2He + n &\rightarrow {}^5_2He \\
{}^5_2He + n &\rightarrow {}^6_2He \\
{}^6_2He &\rightarrow {}^6_3Li + e^- + \bar{\nu}_e. \qquad (42)
\end{aligned}
$$

The heat from the reaction in Eq.(42) is $Q[{}^4_2He + 2n \rightarrow {}^6_3Li + e^- + \bar{\nu}_e] \approx 2.95\ MeV$. The complete nuclear cycle as described in Eqs.(41) and (42) taken together would release a substantial total heat through nuclear transmutations. Other Lithium initiated processes would produce both ${}^4He$ and ${}^3He$.