LENT: Low Energy Nuclear Transmutations General Theory & Experiments

A lecture to honour a friend and a great physicist
Giuliano Preparata
Who paved the way for us to follow

By

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Novembre 23, 2012

@

Istituto Italiano Per Gli Studi Filosofici, Napoli

Giuliano Preparata

A pioneer in

1. Operator Product Expansion
2. Strucutre of Water
3. Memory of Water
4. LENT
5. Free Electron Laser

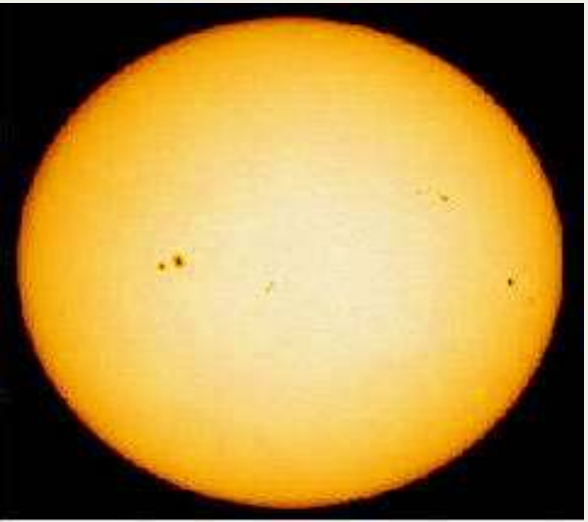
A Born Teacher

Istituto Italiano per gli Studi Filosofici, Napoli

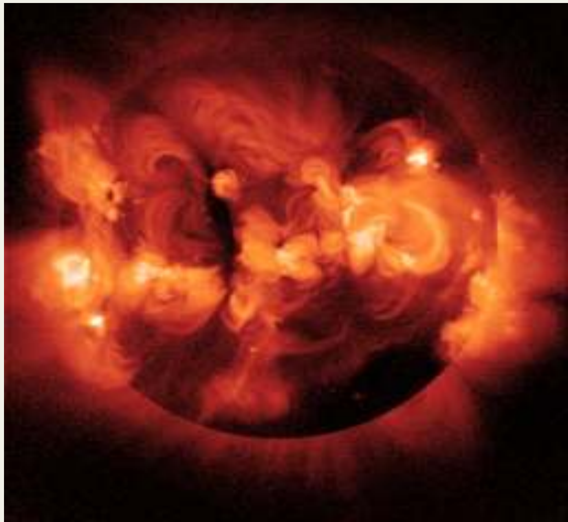
The Sun provides the energy without which no life on Earth would be possible

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

Contents of the Talk: I

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: imaging devices and 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. Piezoelectric crystals when crushed produce LENT.

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?

A footnote about Darwin & Kelvin

1. Lord Kelvin went to Cambridge 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

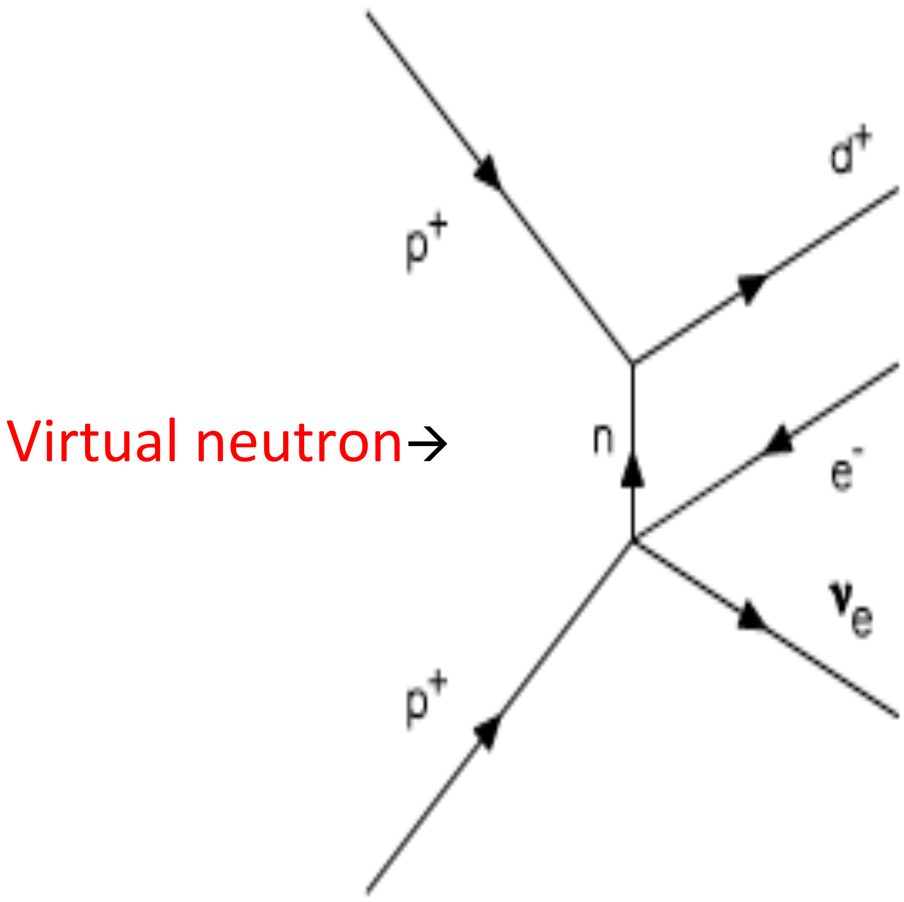


FIG. 1: Shown is the Feynman diagram for the reaction $p^+ + p^+ \rightarrow d^+ + e^+ + \nu_e$ as in Eq.(8).

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: $p + p \rightarrow d + e^{+} + \nu_e$

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

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:

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

2 Deuterons also produce alpha and radiation:

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

A proton with a deuteron produces helium3 & radiation:

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

Finally von Weiszacker-Bethe process is used twice:

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

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

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

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

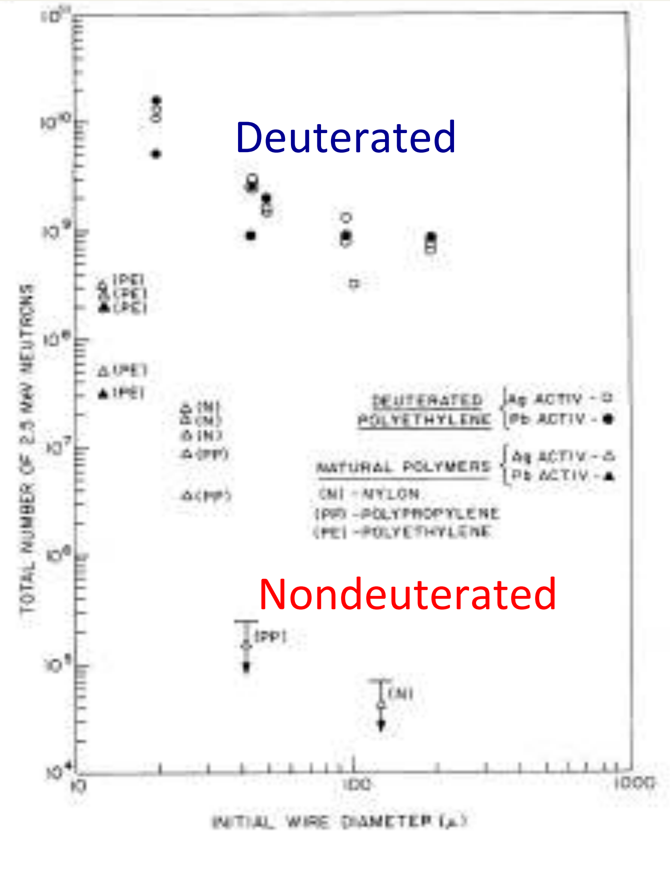


FIG. 1. Variation of neutron yield with initial fiber diameter.

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

But something extraordinary was seen:

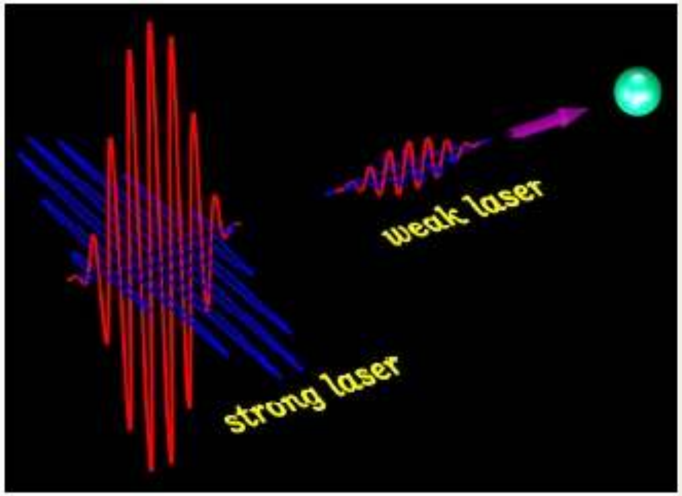
The experiments were also done with normal [nondeuterated] fibers, the yield of neutrons turned out to be 4-5 orders of magnitude higher than expected.

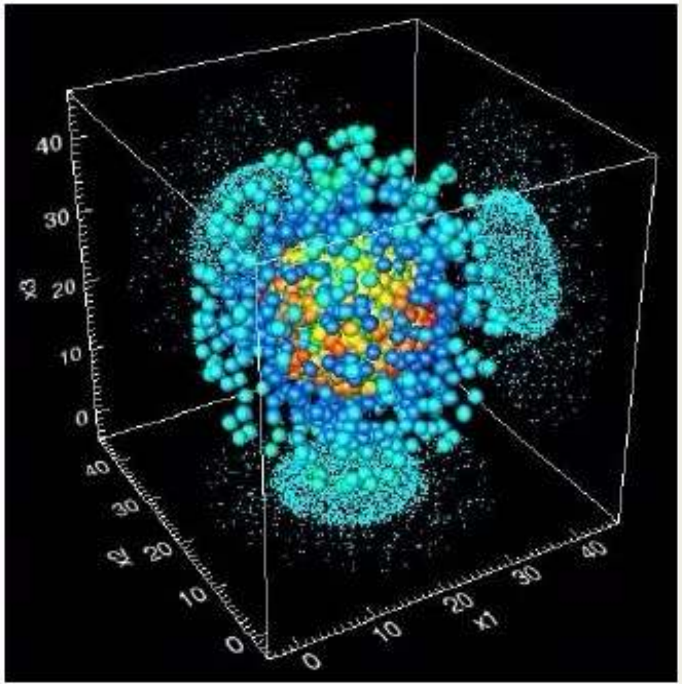
Since in normal wires there are only electrons and protons, we suggested that neutron production is via weak interactions through the collective Darwin term.

Our explanation works quite well

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

Electric LENT I





- **In recent experiments, an exploding molecular clusters 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.

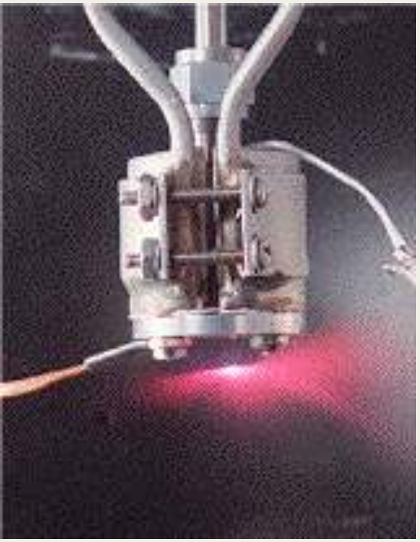
Typical explosion fields are of the order of $eE_c \sim$ GeV/cm

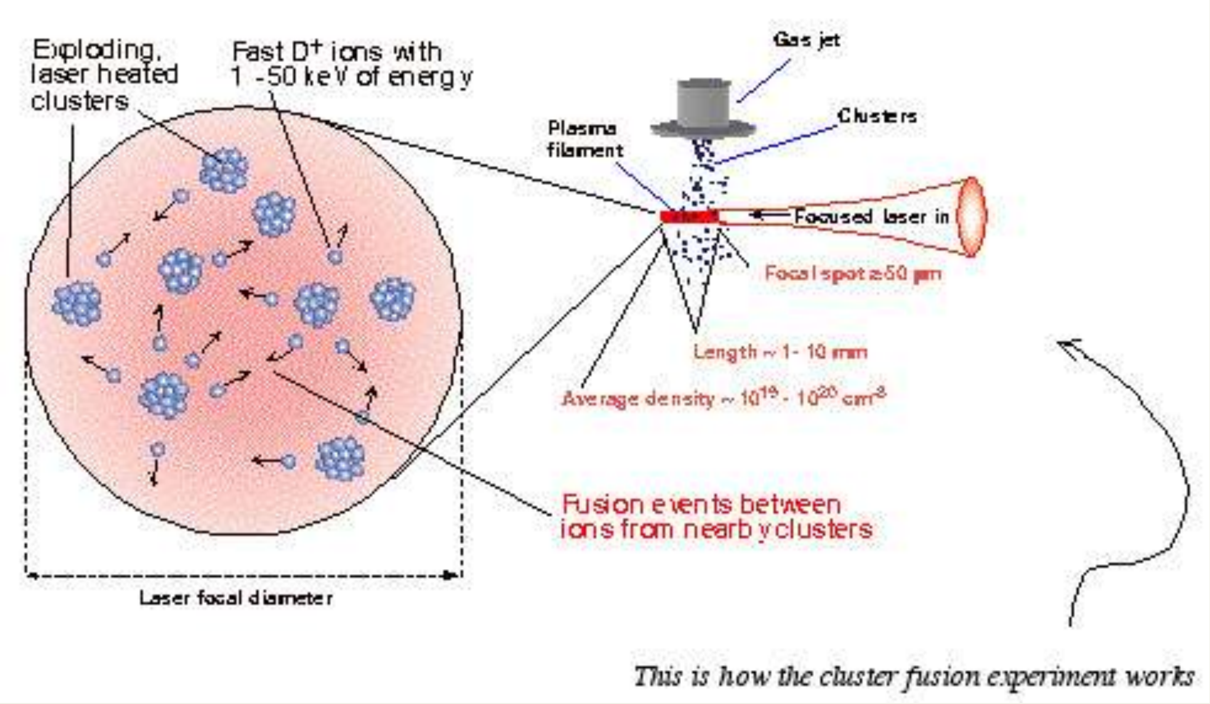
$$E_c = \sqrt{8\pi P_c}$$

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

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

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





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.

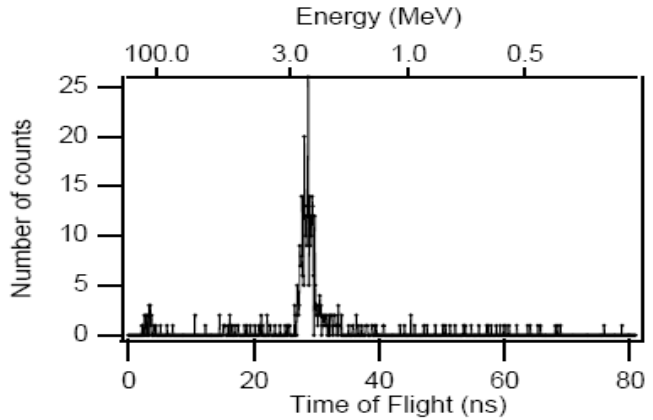


FIG. 1. Neutron time-of-flight spectrum. Neutrons were detected 62 cm from the target using a 7 mm thick plastic scintillator. The peak occurs at 2.45 ± 0.2 MeV, characteristic of DD fusion.

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

Electro-Weak LENT I

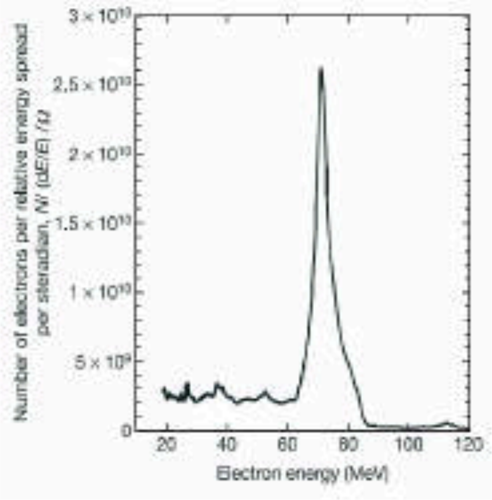
There are essentially three options for accelerating electrons which have produced good results:

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.

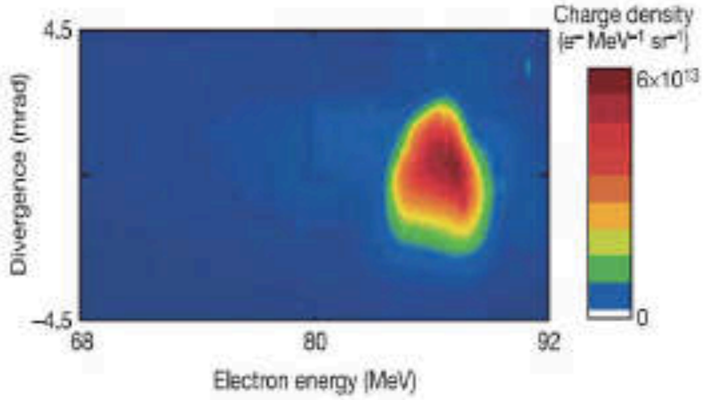
DREAM BEAMS by FAST LASERS I

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

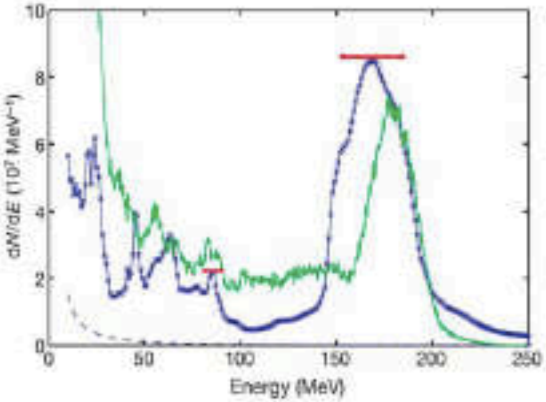
Mangles et al, Imperial College, UK: 70 MeV beam



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

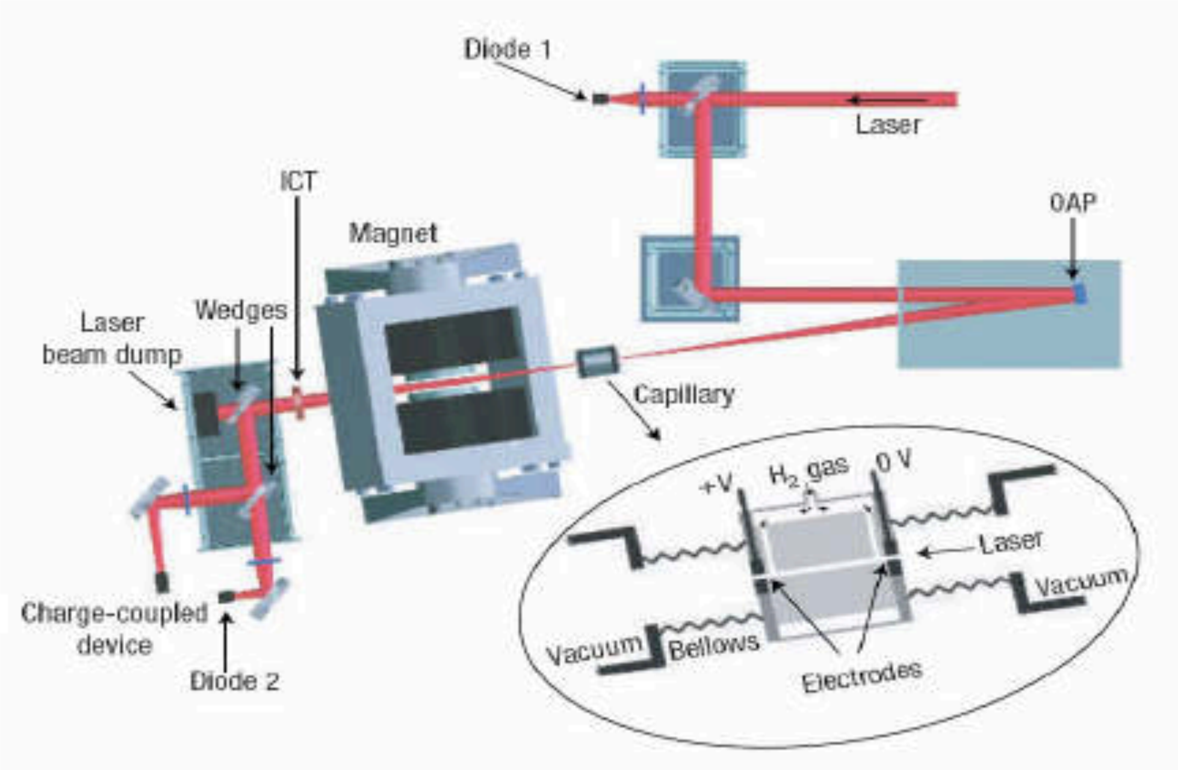
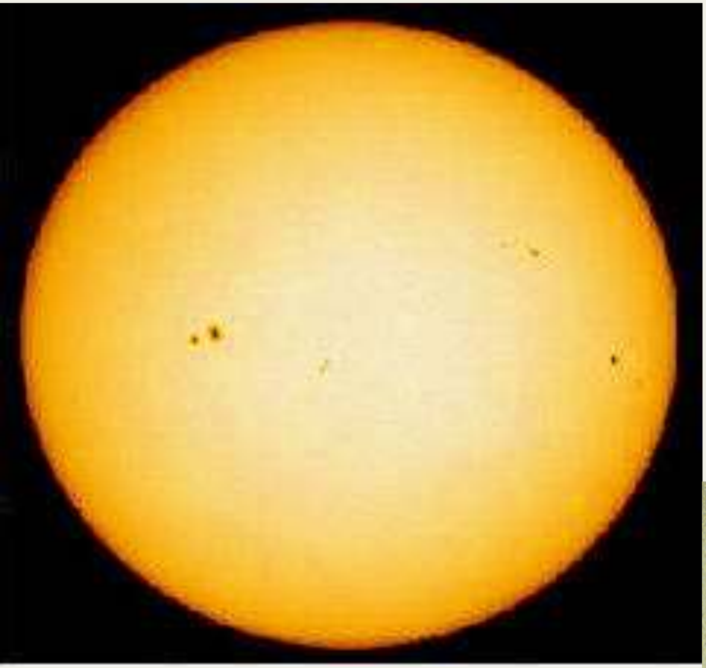
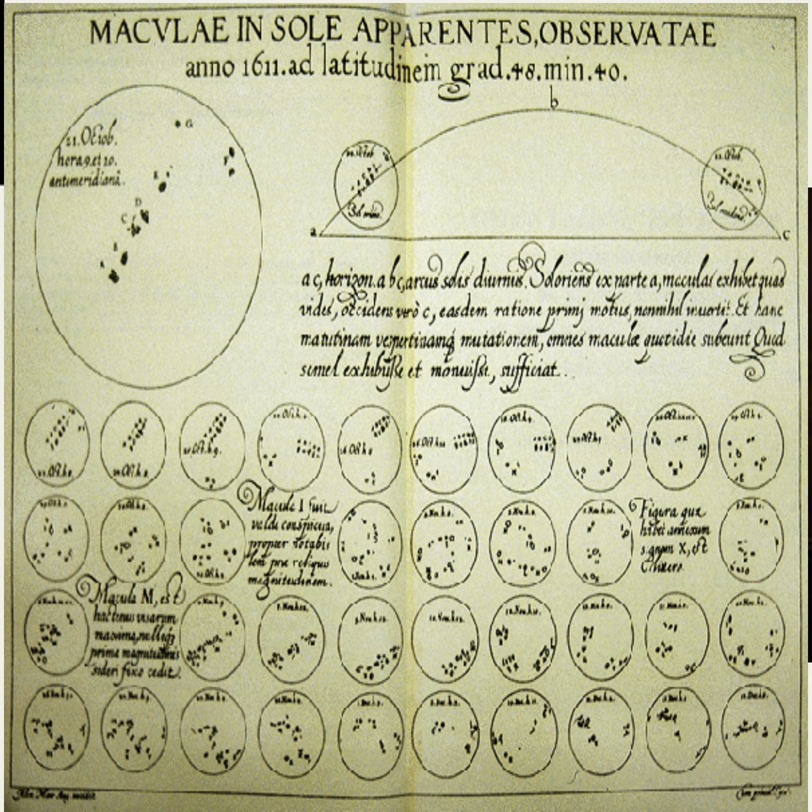


Image taken from Leemans et al., Nature Physics, 2 (2006)

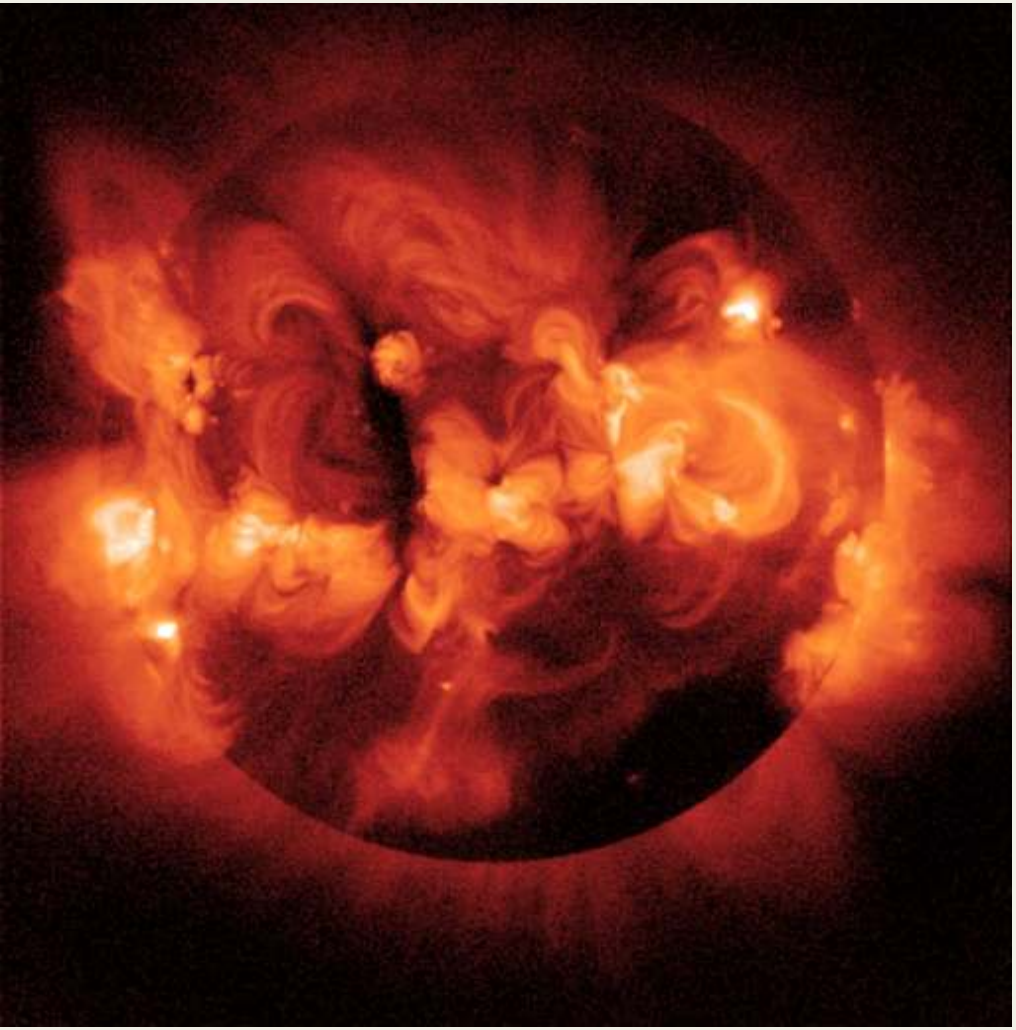
Solar Surface I

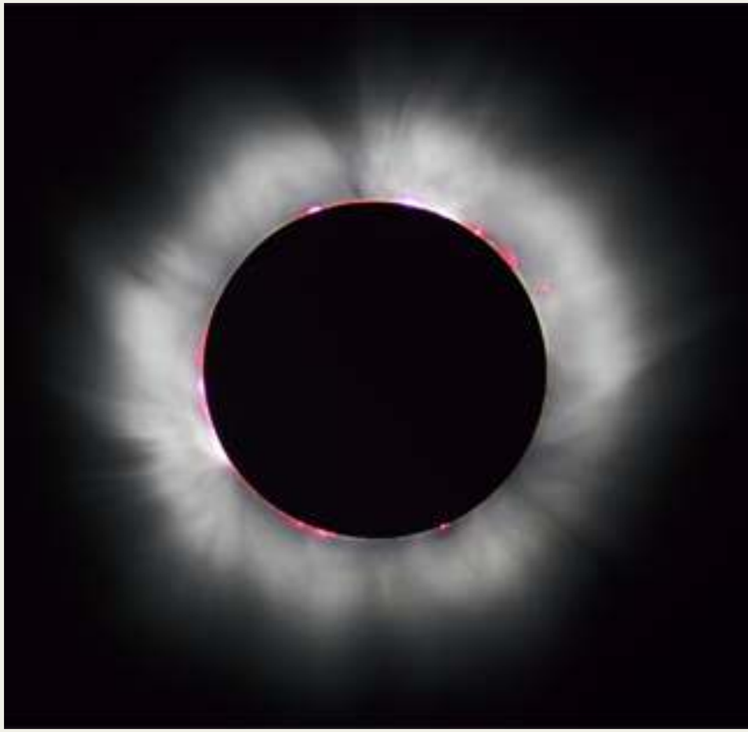


Picture of the sun taken with an optical camera. There is little surface structure beyond a few dark "sunspots"



Solar surface II & Solar Corona

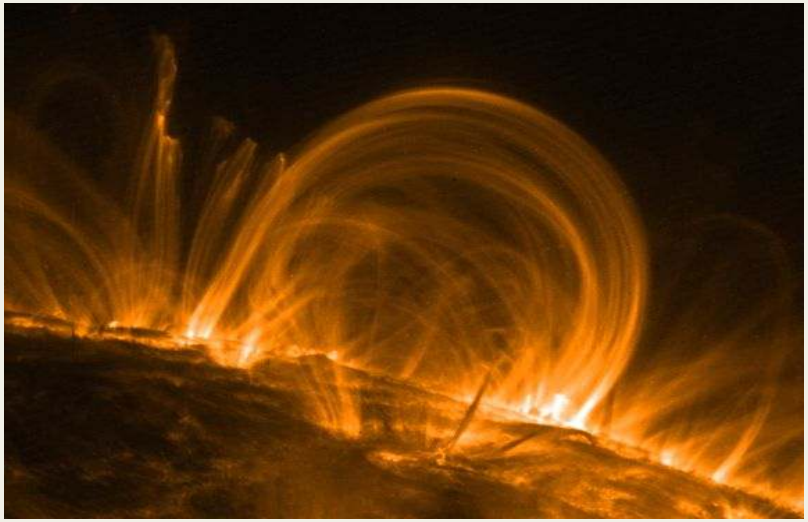


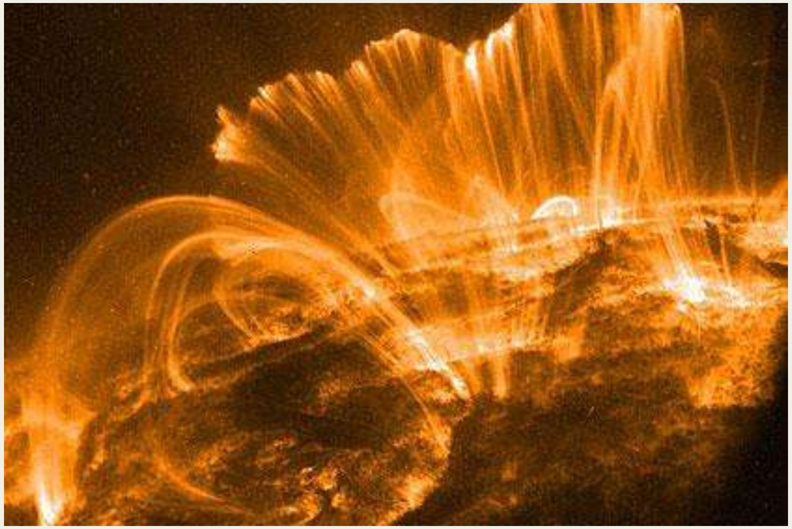


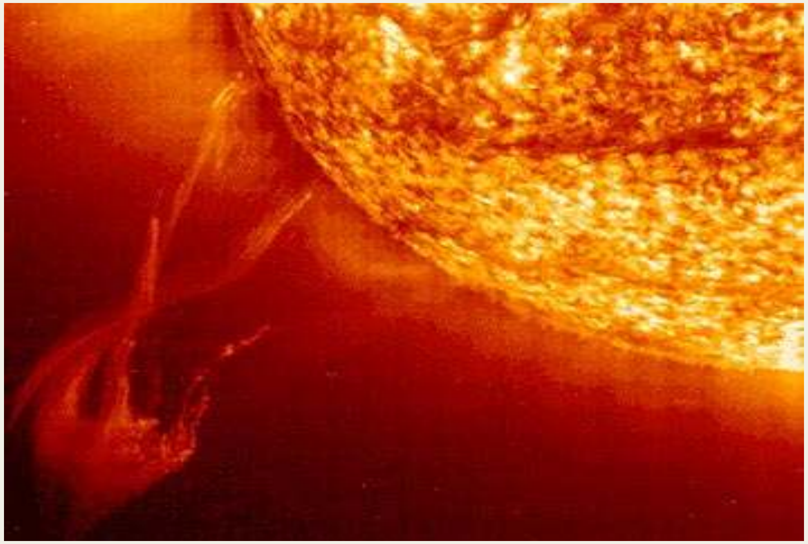
←UV & X-ray pictures

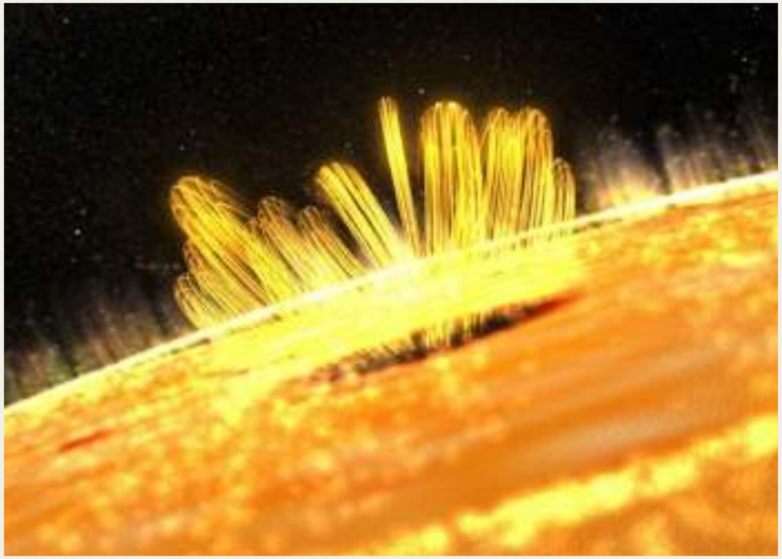
Magnetic Flux Tubes

Exit from one sunspot to dive into another

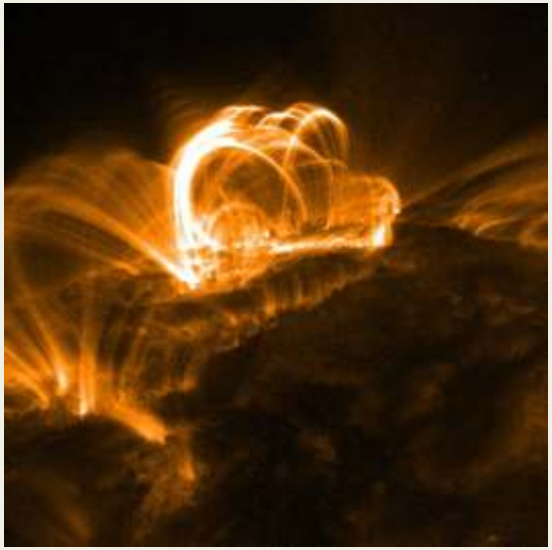


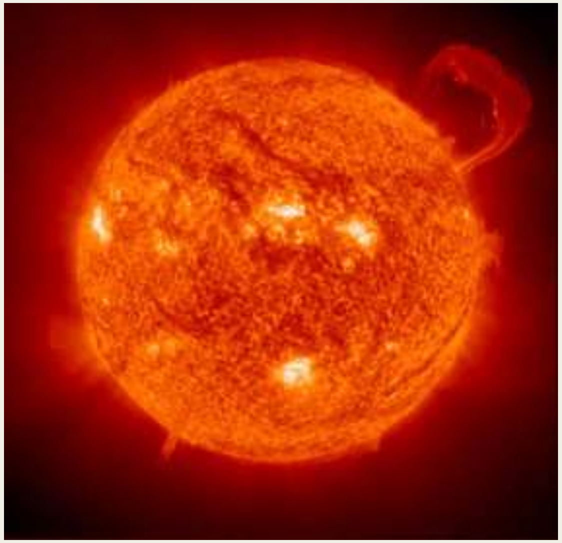






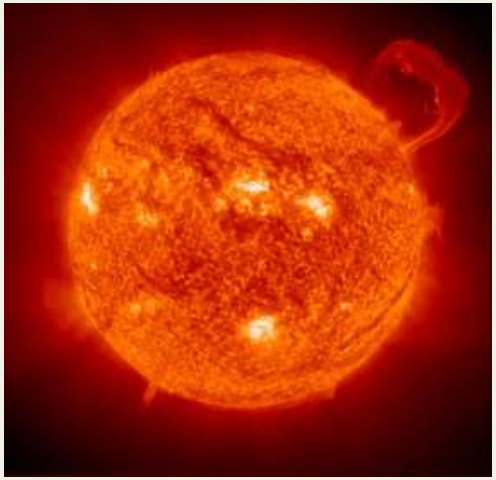
Magnetic Flux Tubes II

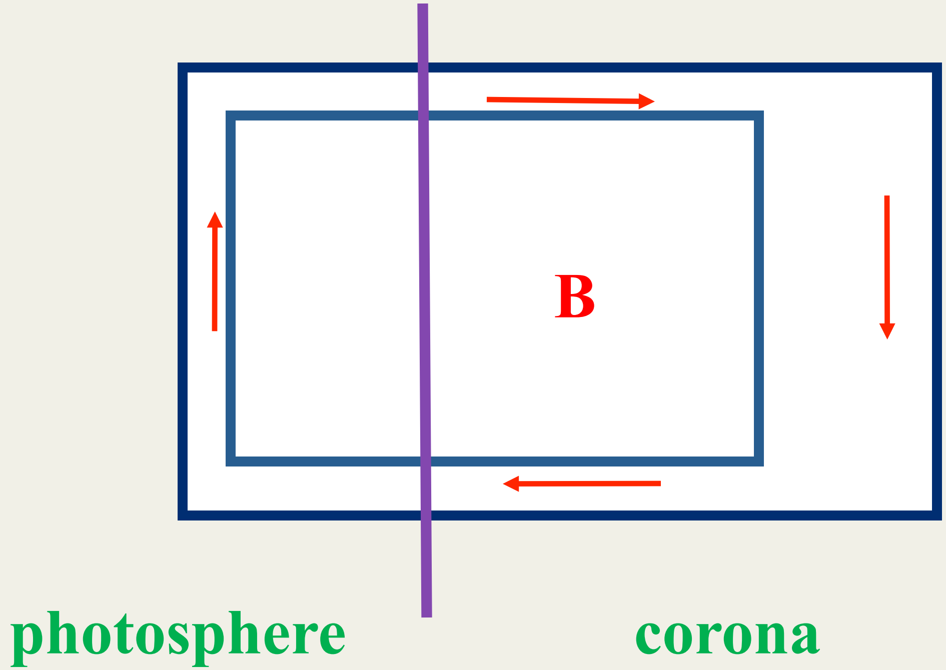


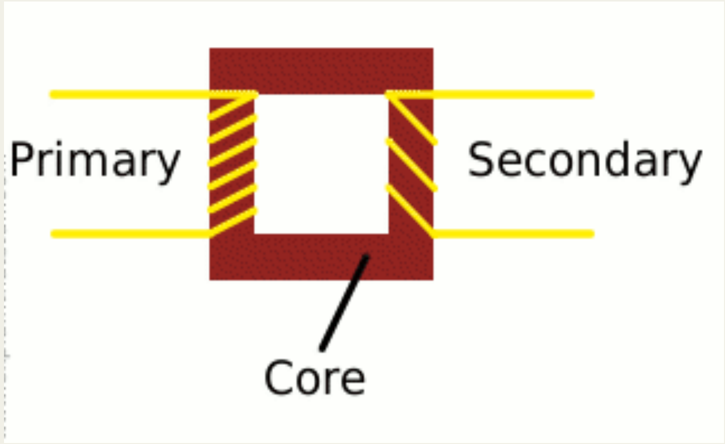


Once in a while magnetic flux tubes break.
Giant Flares from Exploding Flux Tubes
Producing huge amounts of energy. HOW?

Magnetic Flux Tubes III







Solar Flares I

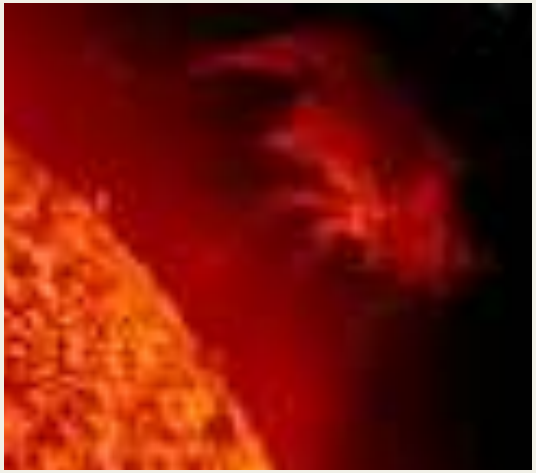
$$e\bar{V} \approx 30\,\text{GeV}\left(\frac{\text{B}}{\text{kiloGauss}}\right)\left(\frac{\pi\,\text{R}}{\text{c}\Delta\,\text{t}}\right)\left(\frac{\text{R}}{\text{kilomoter}}\right)$$

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

$$\Delta\text{t} \sim 10^2\,\text{sec}$$

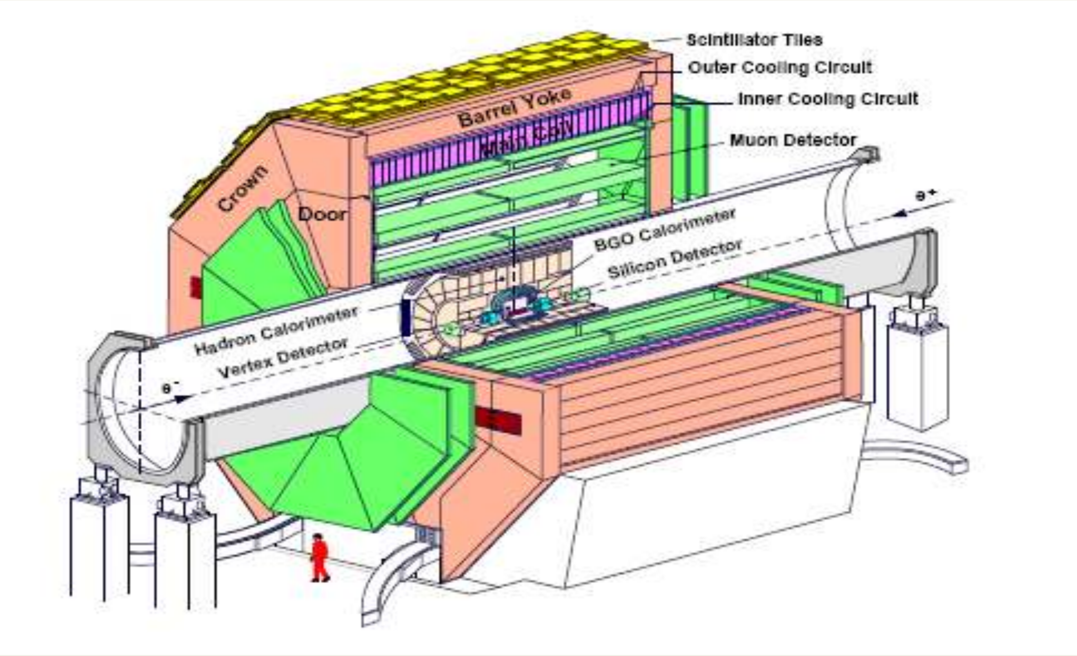
$$R \sim 10^4\,\text{kilomoter}$$

$$e\bar{V} \sim 300\ \text{GeV}$$



Faraday Law
Betatron 300 GeV
electron – proton
collider

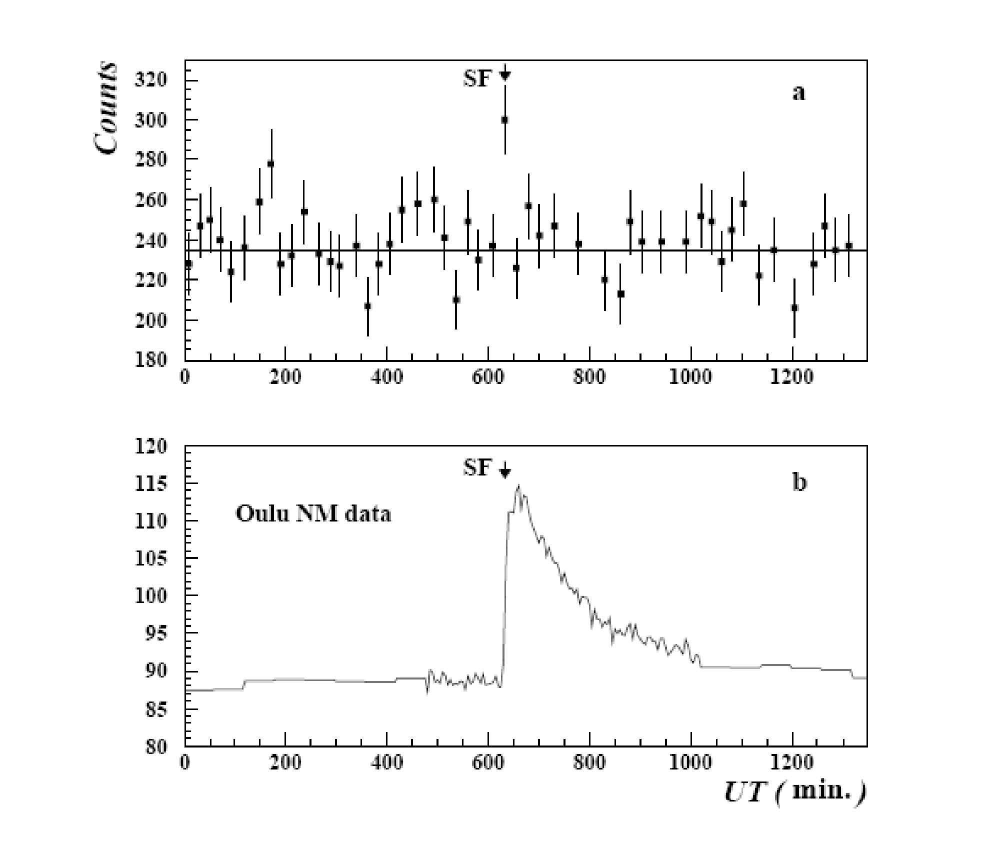
Solar Flares II



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

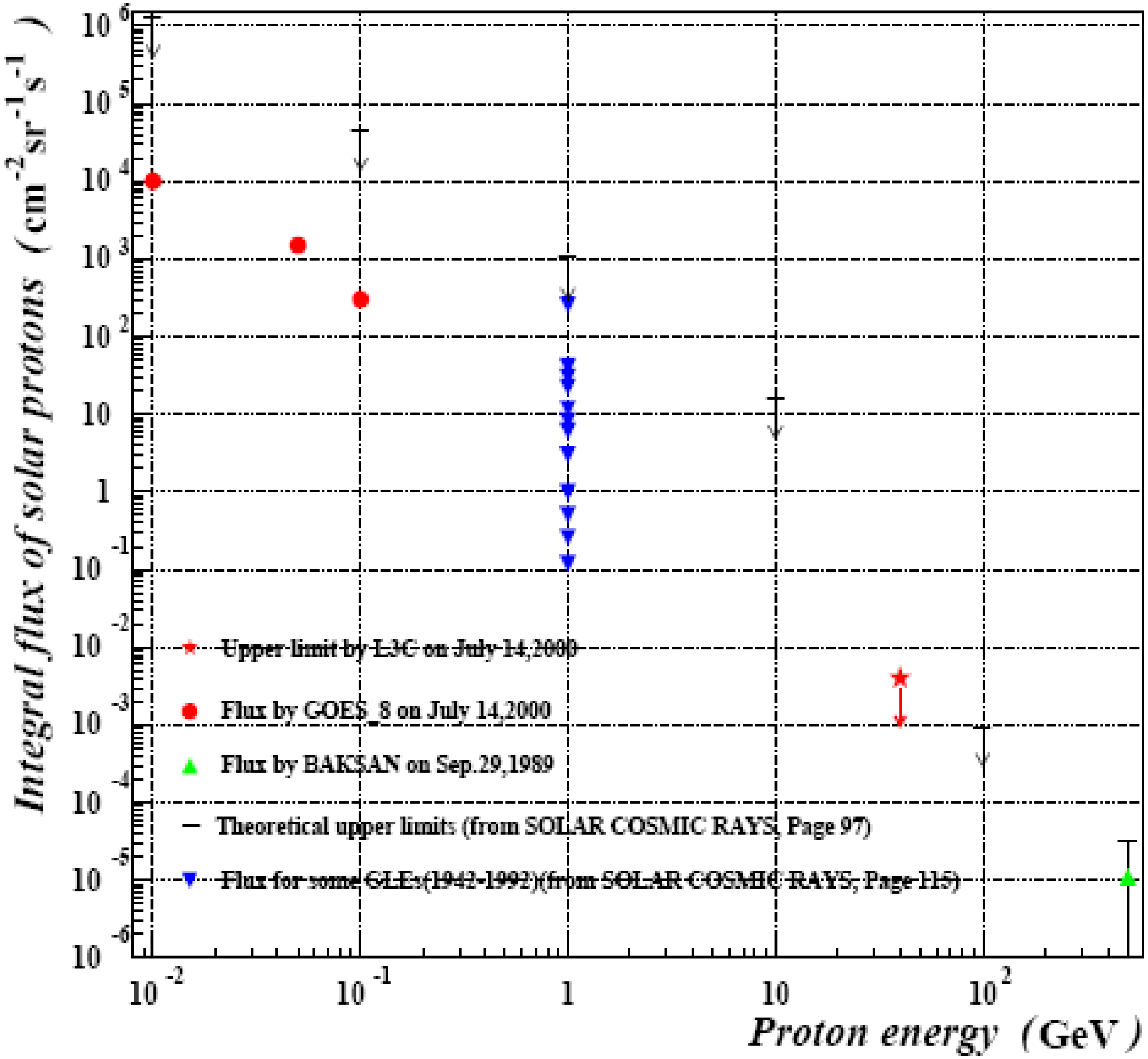
The time when the peak occurred at CERN in Geneva(TOP) matches exactly as to when neutron monitors (NM) at Oulu (Below) saw peak in their signals from the Solar Flare (SF).



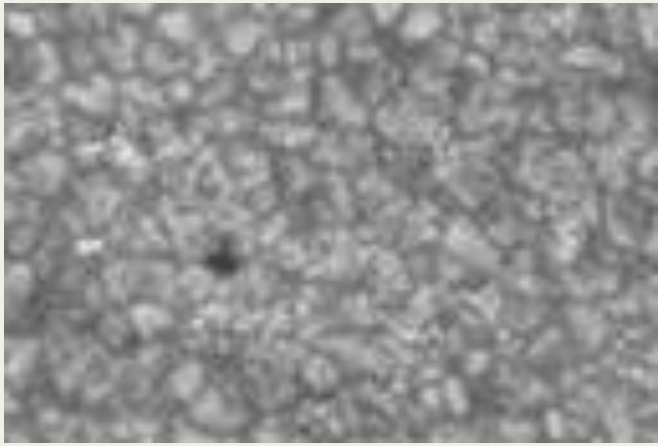
Number of events as a function of time in minutes for the whole day (14th July 2000) in sky cell No.37. The solar flare time is 10:30 UT is marked by `SF'. The live-time bin width is 16.78 minutes. The solid line shows the mean value of the background.

Solar Flares IV

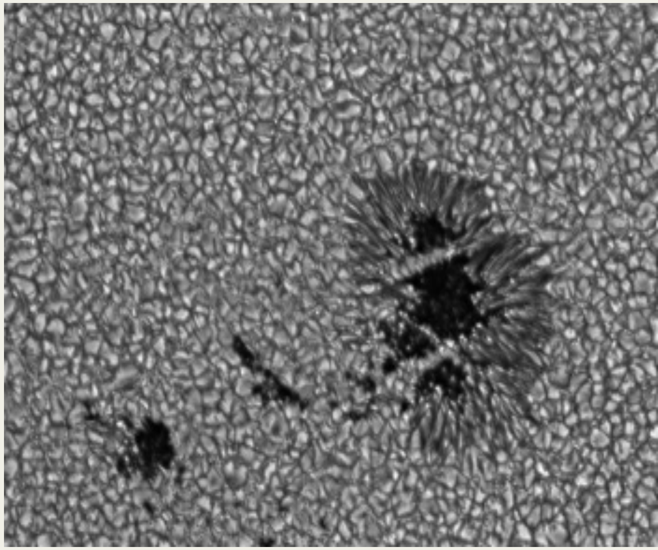
Low energy protons (shown on the left by red dots) are from the core of the Sun. High energy protons on the right are from giant Solar flares



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:

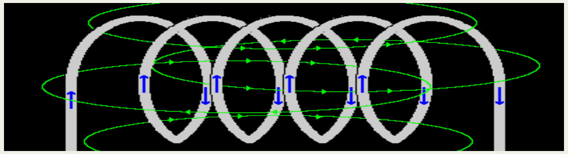
$$W_{magnetic} + e^- + p^+ \rightarrow n + \nu_e$$

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

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

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

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



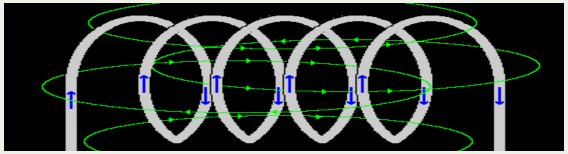
$$W_{magnetic} = eB\left(\frac{\Delta S}{L}\right)\frac{v}{c}$$

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

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

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

Single Threaded Coils II

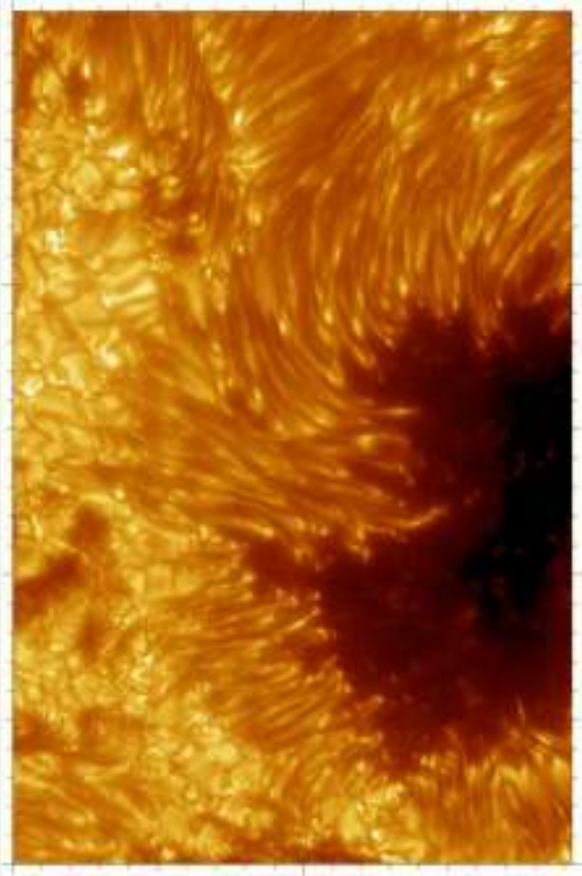


$$W_{magnetic} \approx (15\,\mathrm{GeV})\left(\frac{B}{\mathrm{kiloGauss}}\right)\left(\frac{R}{\mathrm{kilometers}}\right)\frac{\mathrm{v}}{c}$$

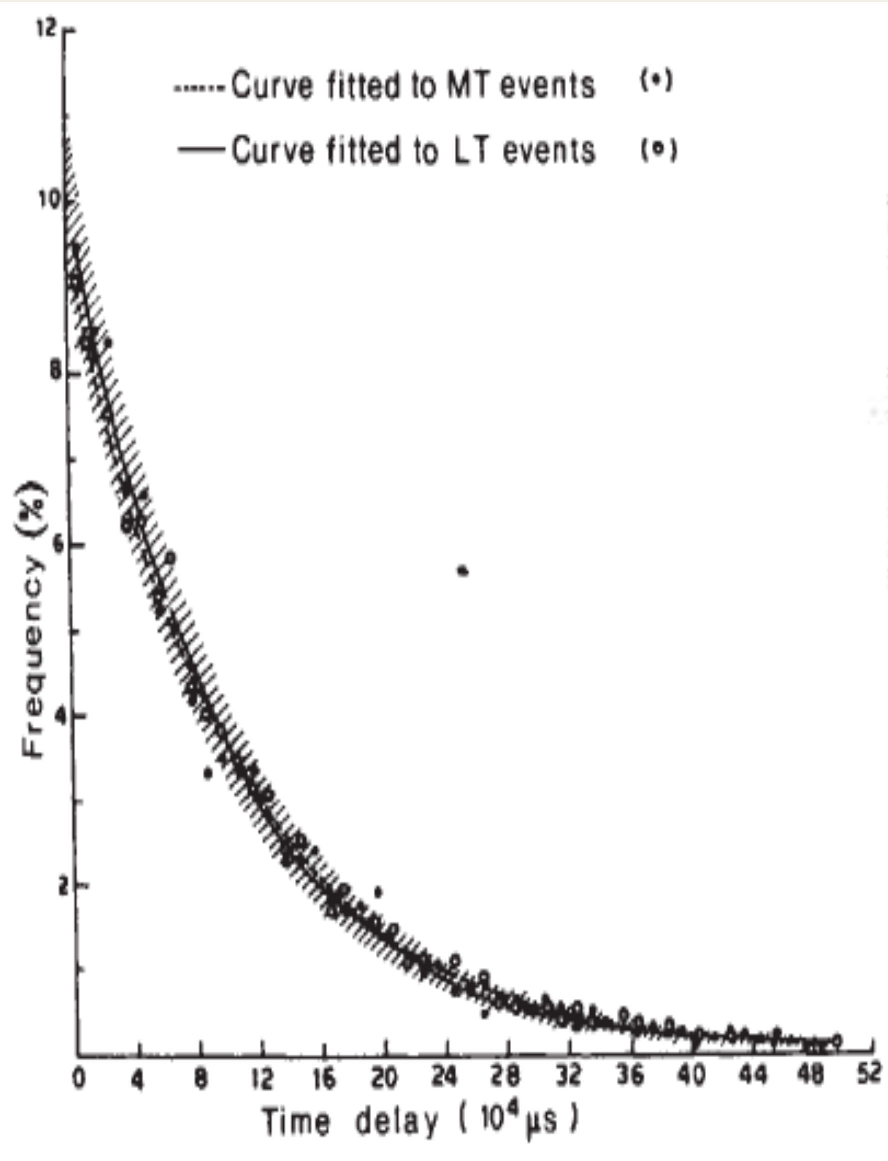
$$B \sim 1\,\mathrm{kiloGauss} \quad R \sim 10^{2}\,\mathrm{kilometers} \quad \frac{\mathrm{v}}{c} \sim 10^{-2}$$

$$\boldsymbol{W_{\mathrm{magnetic}} \sim 15\ \mathrm{GeV}}$$

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



Lent in Nature: Neutrons from Lightning



Neutron generation in lightning bolts

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

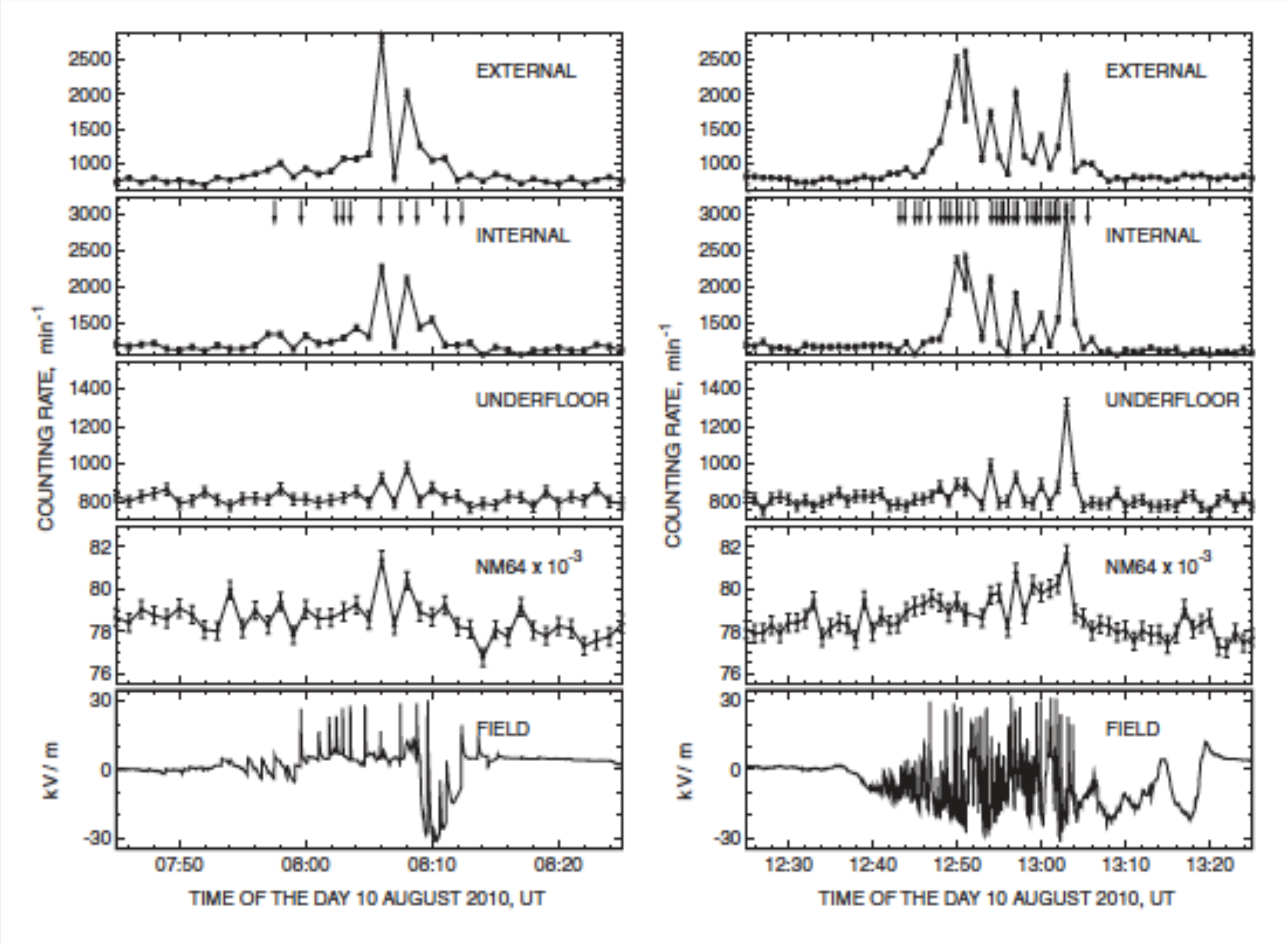
Bhabha Atomic Research Centre, Nuclear Research Laboratory, Zakura, Naseem Bagh, Srinagar-19006, Kashmir, India

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 γ- 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.

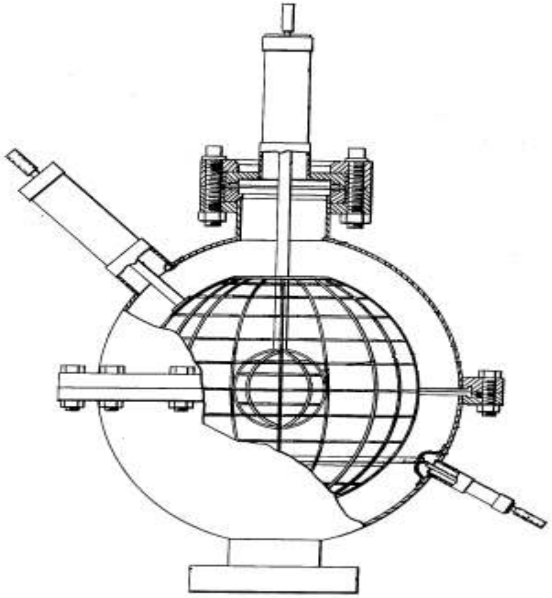
The explanation, employing the standard electroweak model, as due to the neutron producing reaction

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

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.

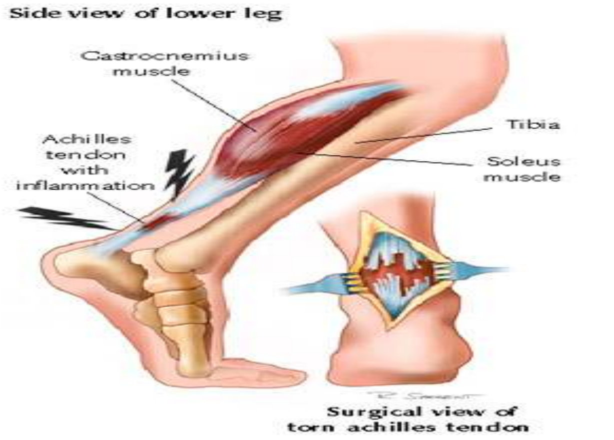
A quick internet search will reveal that fusors are a popular science fair projects built by students.

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
β	Piezoelectric constant

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

Neutron Production from the Fracture of Piezoelectric Rocks

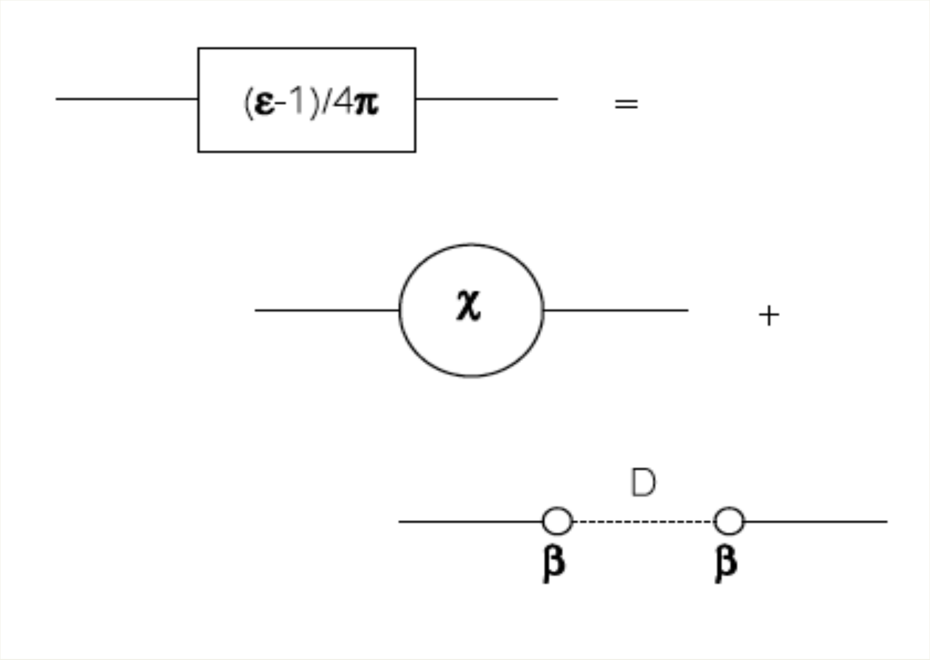
[Accepted for publication]

Neutron production from fracturing rocks [WSS]: III

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

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

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



- *D_{ijkl}* is the phonon propagator
- ε_{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 β_{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 σ_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