

Compte rendu (extraits)
**Office parlementaire d'évaluation
des choix scientifiques et technologiques**

- Audition, ouverte à la presse, du Professeur Gérard Mourou, prix Nobel de physique 2018

https://www.assemblee-nationale.fr/dyn/15/comptes-rendus/ots/l15ots1819038_compte-rendu.pdf

Jeudi 14 février 2019

Séance de 9 h 30

Compte rendu n° 38

session ordinaire de 2018-2019

Présidence

M. Gérard Longuet, président

A PASSION FOR EXTREME LIGHT

For the greatest benefit to human kind (Alfred Nobel)



Transmutation des Déchets Nucléaires

Presented by

Prof. Gérard Mourou

Nobel Prize for Physics, 2018



Toshiki Tajima

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Gérard Mourou

Donna Strickland

**PRIX NOBEL de
PHYSIQUE 2018**

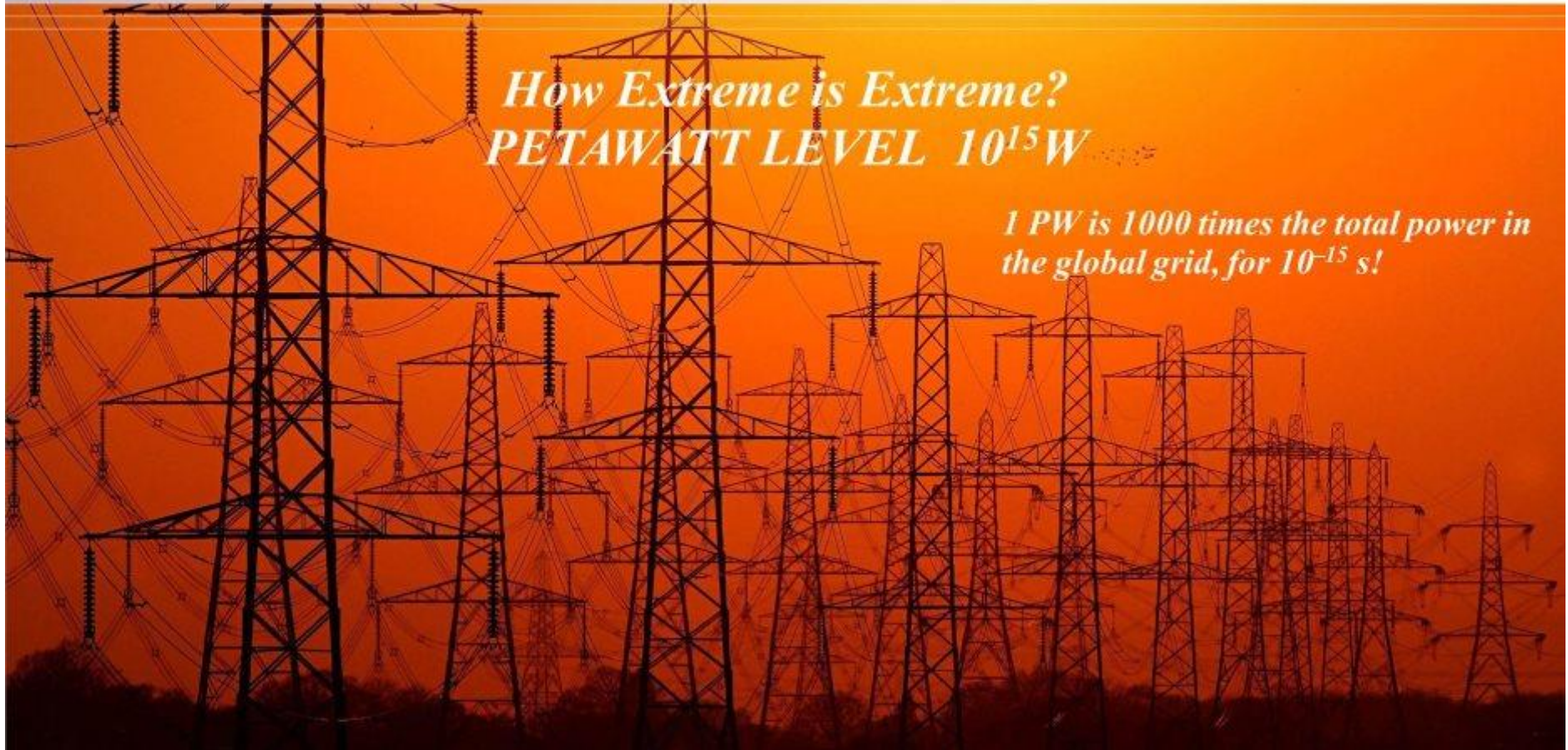
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How Extreme is Extreme?
PETAWATT LEVEL $10^{15}W$

*1 PW is 1000 times the total power in
the global grid, for 10^{-15} s!*



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How Much Pressure Does a PW Laser Exert?

*1 PW/1 μ m spot size
corresponds to 10^{23} w/cm²*

*That is the equivalent of the
pressure of 10 million Eiffel
Towers on the tip of your
finger!!*

Seriously extreme!





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LA LUMIERE EXTREME:

Fournit les intensités les plus élevées,
Les champs électriques les plus grands,
Les pressions les plus importantes,
Les accélérations les plus grandes
Les températures les plus élevées

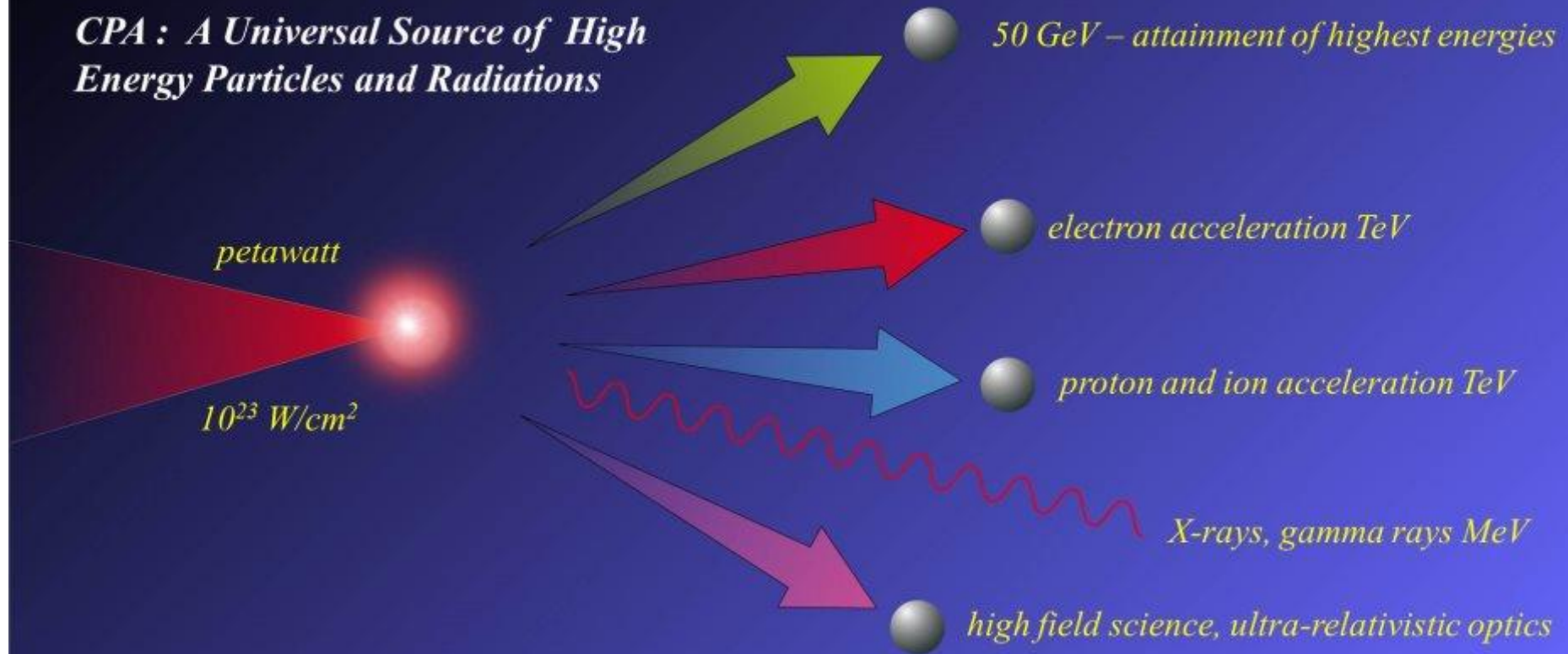
Elle est la source universelle de particules et de radiations de haute énergie.

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CPA : A Universal Source of High Energy Particles and Radiations

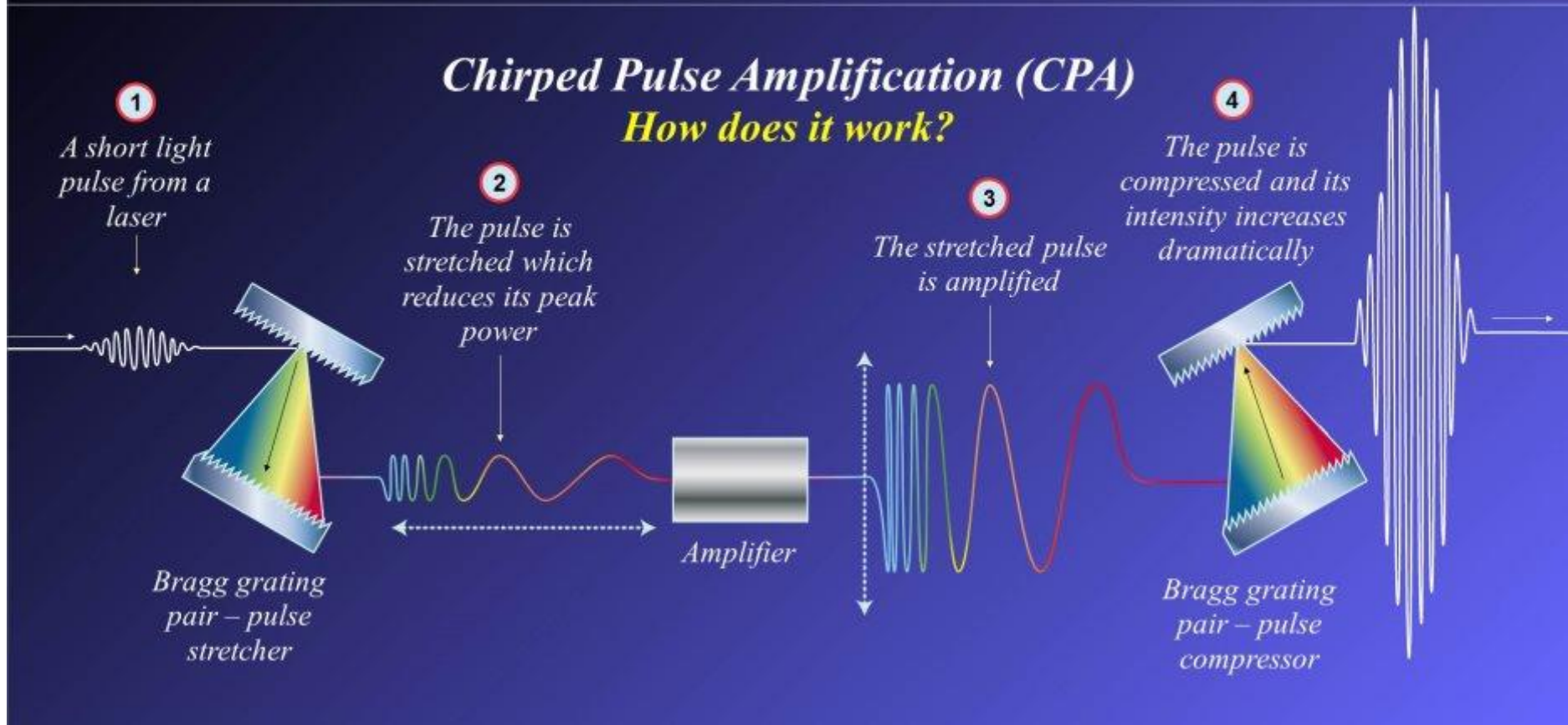


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Chirped Pulse Amplification (CPA) How does it work?



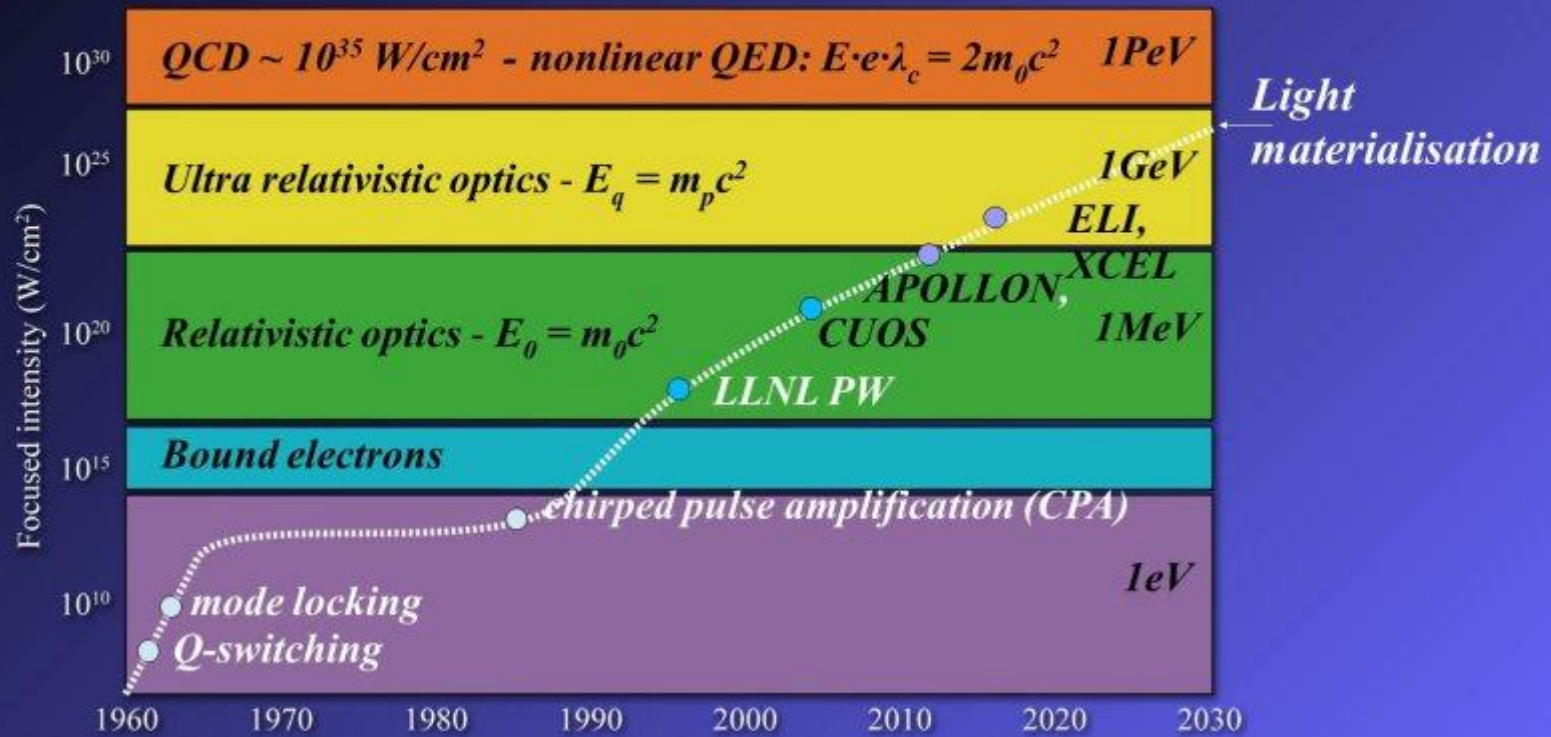
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Extreme light ultra high intensity roadmap

EXCEL



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ACCELERATION DE PARTICULES



laser pulse

electrons

plasma wave

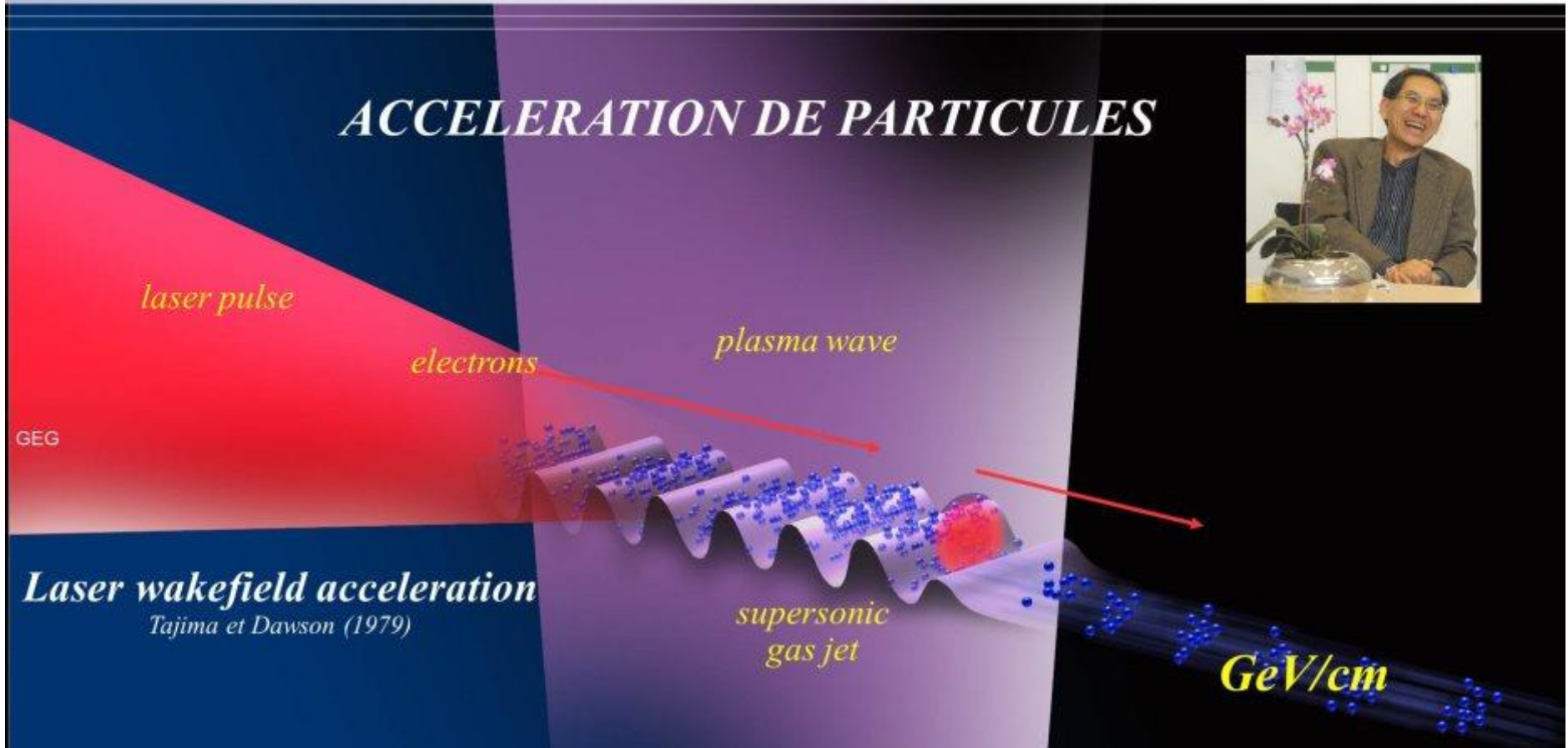
GEG

Laser wakefield acceleration

Tajima et Dawson (1979)

*supersonic
gas jet*

GeV/cm



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Synchrotron SOLEIL 3GeV



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Giant wakefield acceleration in solid

Tajima et Dawson (1979)

Laser-particle accelerations to the TeV/cm level become possible

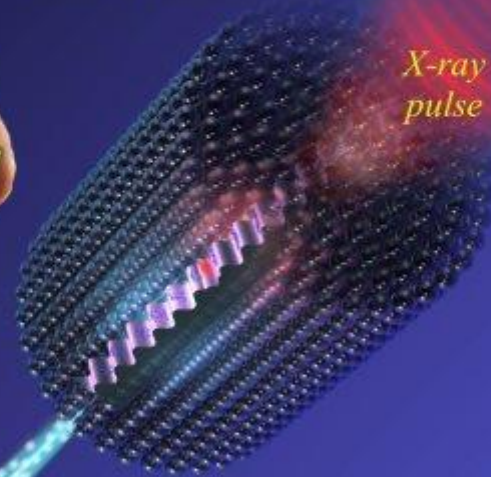
*X-ray
pulse*

Tomorrow

- * visible laser induced wakefield
- * about 100 metres long
- * the size of a football pitch

Beyond tomorrow

- * laser induced X-ray wakefield
- * about TeV/cm
- * the size of a microchip



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CPA in Nuclear Medicine

Proton therapy



*Extreme light technology
will be tens of times more
compact, more precise and
less expensive*

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CPA in Nuclear Medicine

Proton therapy



*Extreme light technology
will be tens of times more
compact, more precise and
less expensive*

Nuclear therapy



*Radionuclides are
used to implant
radioactive pellets
directly into a tumour*

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CPA in Nuclear Medicine

Proton therapy



Extreme light technology will be tens of times more compact, more precise and less expensive

Nuclear therapy



Radionuclides are used to implant radioactive pellets directly into a tumour

Nuclear diagnostics



When a scanner needs a radioisotope, extreme laser acceleration in the clinic would make this fast and safer

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CPA Mitigating Nuclear waste



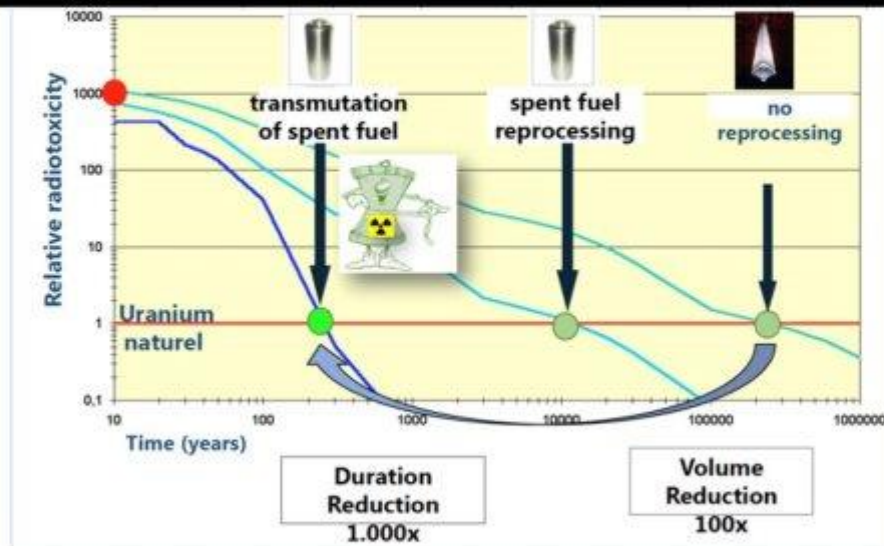
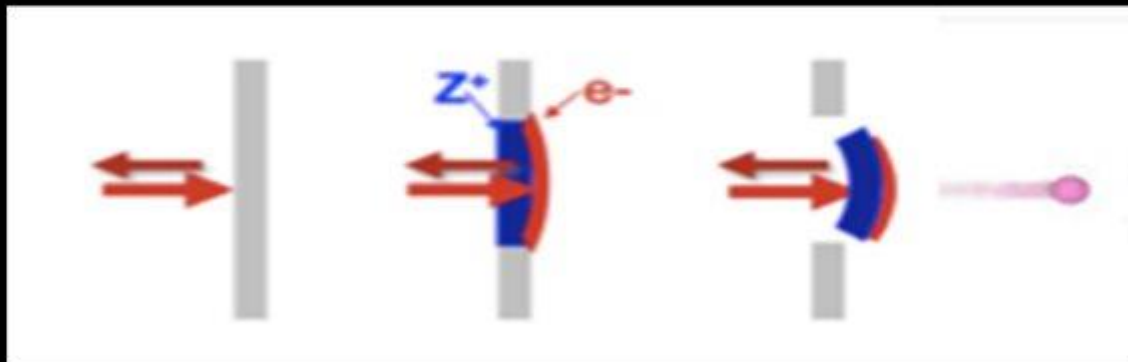


Figure 1: The radiotoxicity of the spent nuclear fuel may be reduced from the level of no reprocessed case to a level reduced by about 1000 times if we transmute the spent fuel. This is why the substantial benefit may be gained by the transmutation. [10],[11]

Low Hanging Fruit: High Energy Proton Generation

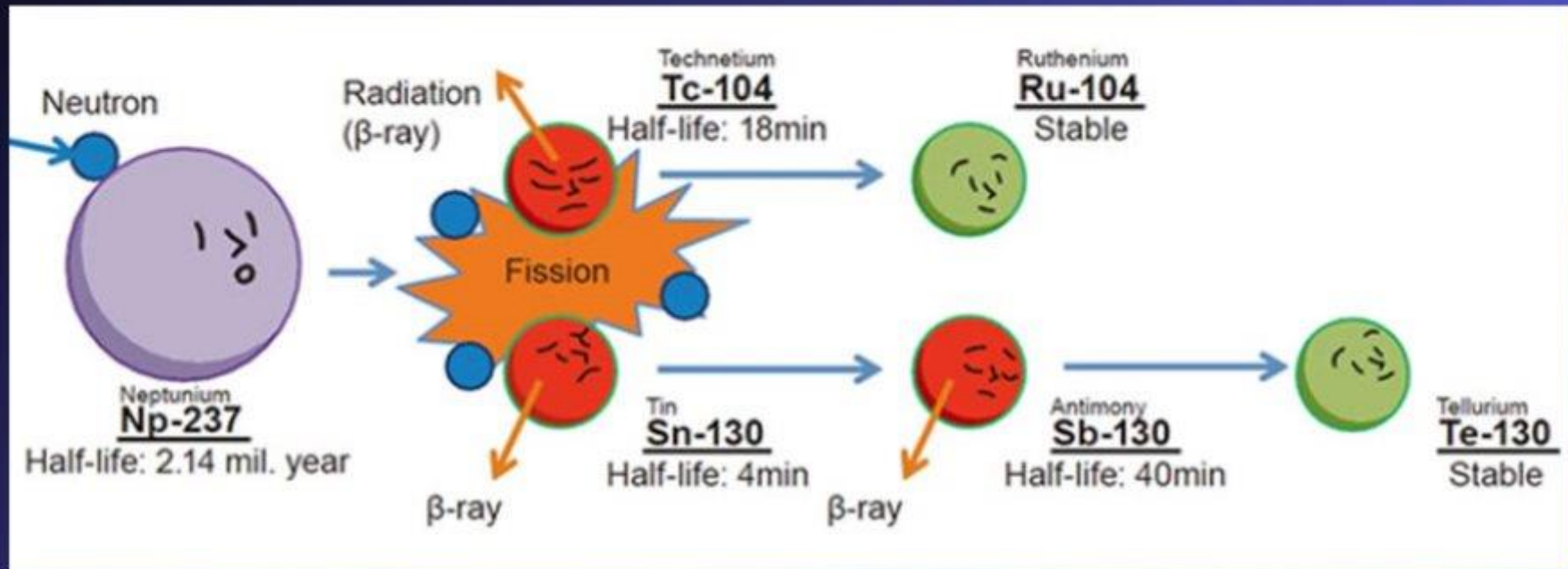
GeV Proton Generation



MeV-GeV



NUCLEAR TRANSMUTATION CONCEPT

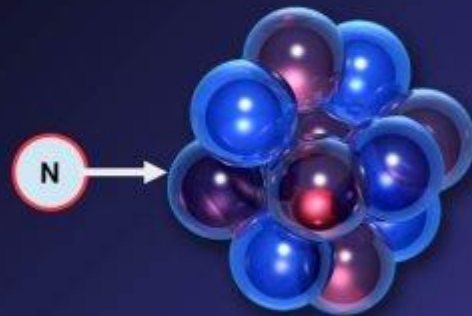




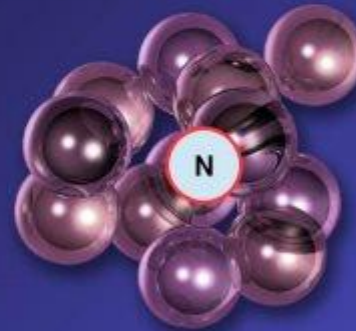
CPA Transmutation of Nuclear Waste

For example

- * ^{99}Tc (Technetium) half-life of 200 000 years
- * ^{100}Tc has a half-life of 16 seconds
- * it decays to a stable ^{100}Ru (Ruthenium)



Isotope A
 $T = 200\ 000\ \text{years}$



Isotope B
 $T = 16\ \text{secs}$



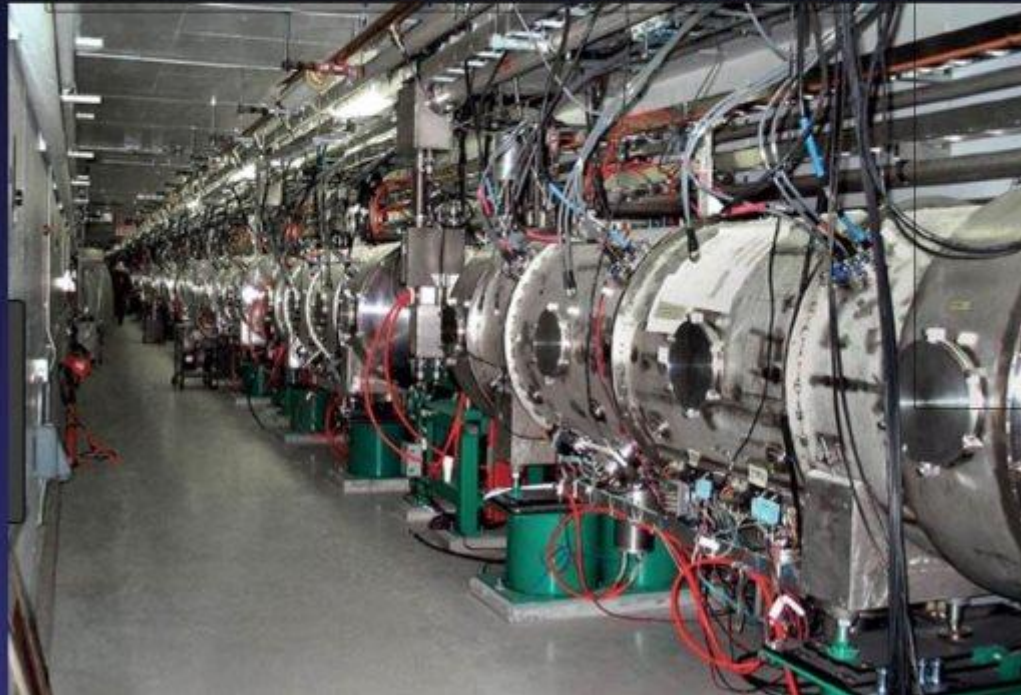
Isotope C
no radiation

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**RELATIVISTIC PROTON ACCELERATOR
for
TRANSMUTATION**



Projet MYRRHA

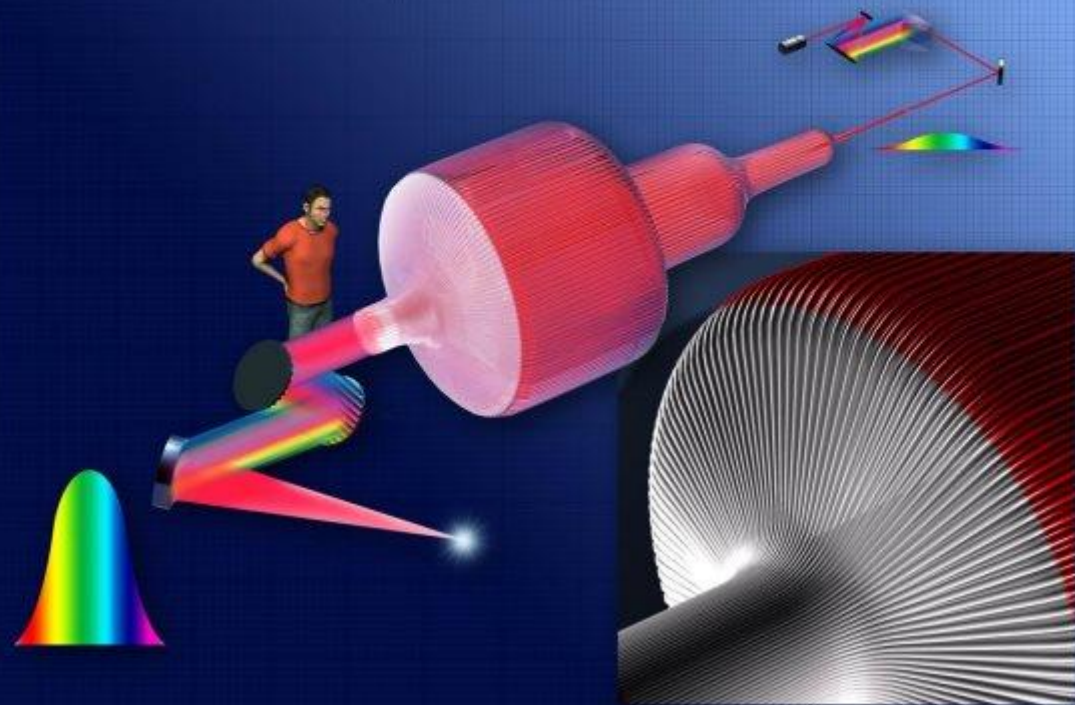
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CAN

Peak Power TW
Average Power MW
Efficiency: 40%

Projet EP-Thales





CONCLUSION

1. La lumière extrême offre des possibilités considérables, à la recherche, l'innovation mais aussi à l'industrie française et européenne.
2. Elle a eu un énorme impact sur l'industrie française du laser. Elle a permis à celle-ci d'innover et de dominer le marché mondial.
3. Je suis heureux qu'avec le CNRS et la Commission Européenne nous ayons pu réaliser les projets ELI et Apollon et contribuer à l'unification de la science dans les pays émergents de l'Union Européenne.
4. Heureux aussi de contribuer au leadership de la recherche Française et Européenne dans le monde.

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And the Best is Yet To Come !

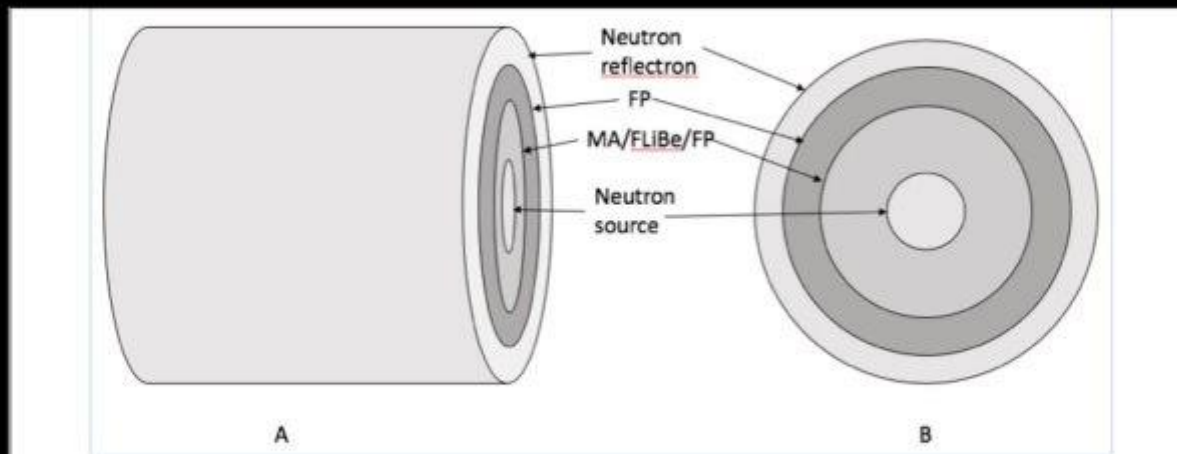


Figure 2. The structure of the liquid state layers of the solution (FLiBe) with TRU and FP surrounding the central fusion neutron source. The schematics, whose more functional details are shown in Fig. 9,

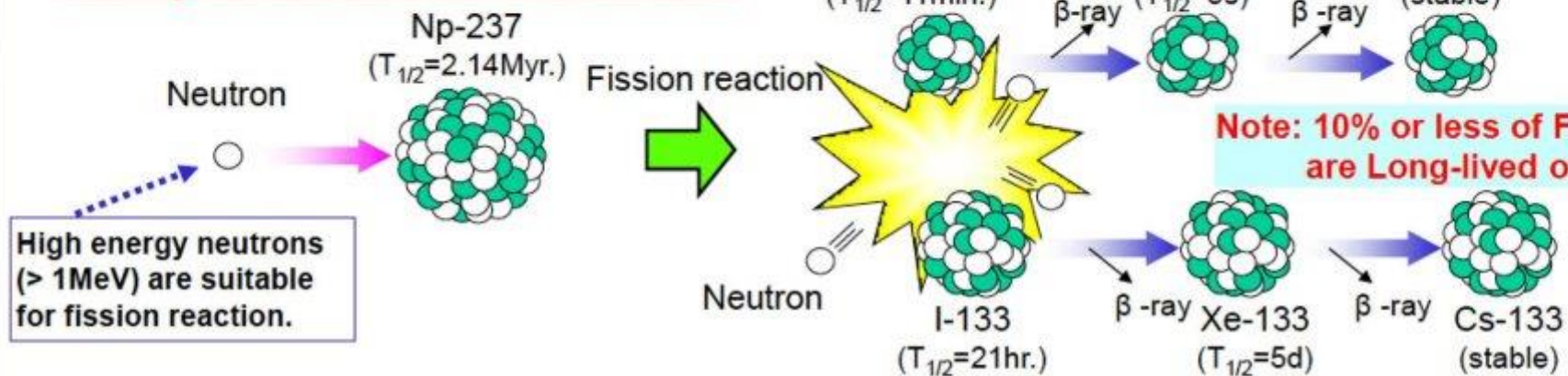


NUCLEAR TRANSMUTATION CONCEPT

How to Transmute MA and LLFP



Example of fission reaction of MA



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*Changing the Future With CPA
Extreme Light Infrastructure (ELI)*

ELI Beamlines
Dolní Břežany, Czech Republic

ELI Attosecond
Szeged, Hungary

ELI Nuclear Physics
Magurele, Romania

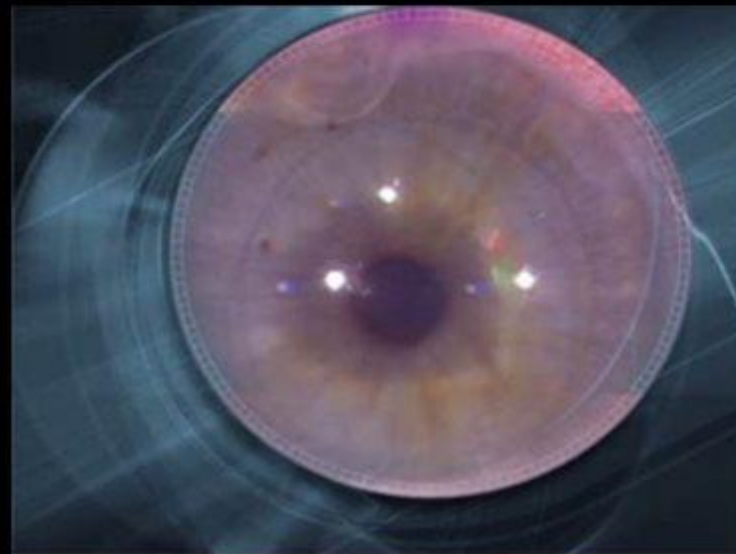


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Intralase flap creation

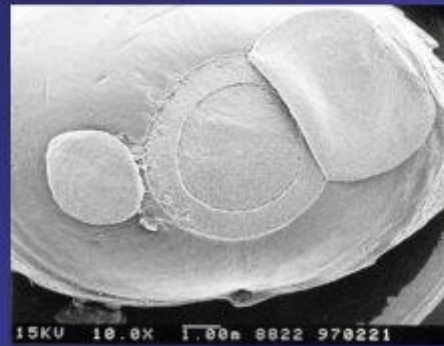
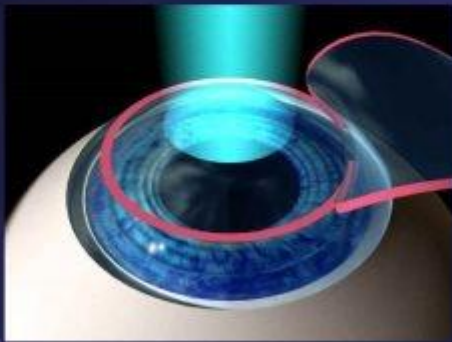


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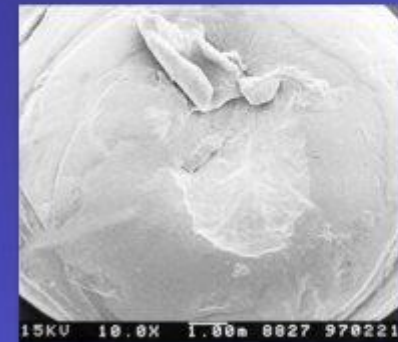
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*CPA femtosecond lasers revolutionised ophthalmology
24 million eye operations since 2001!*



300 femtosecond



50 picosecond

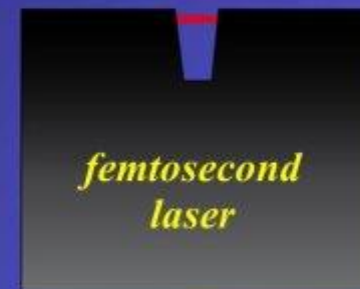
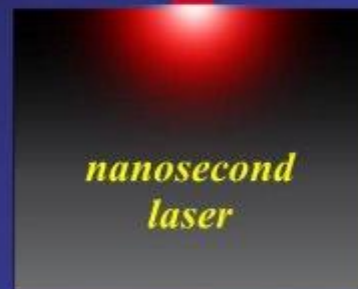
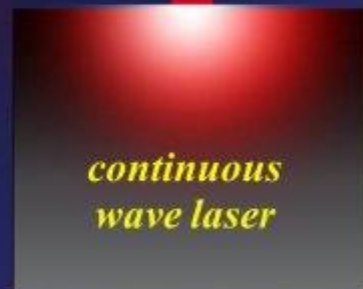
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High Precision Micro Machining

A femtosecond (fs) laser will cut the material without damaging it



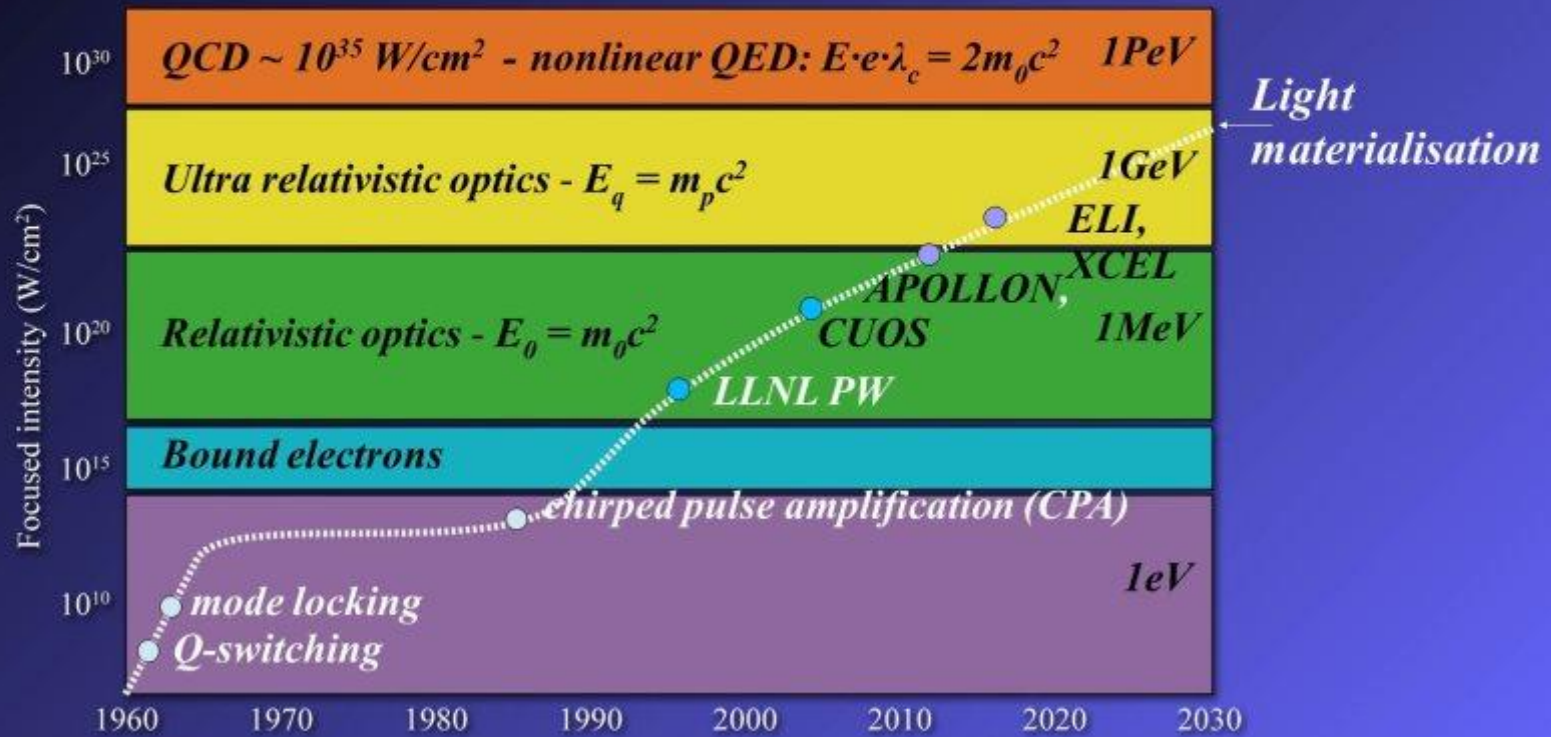
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Extreme light ultra high intensity roadmap

EXCEL

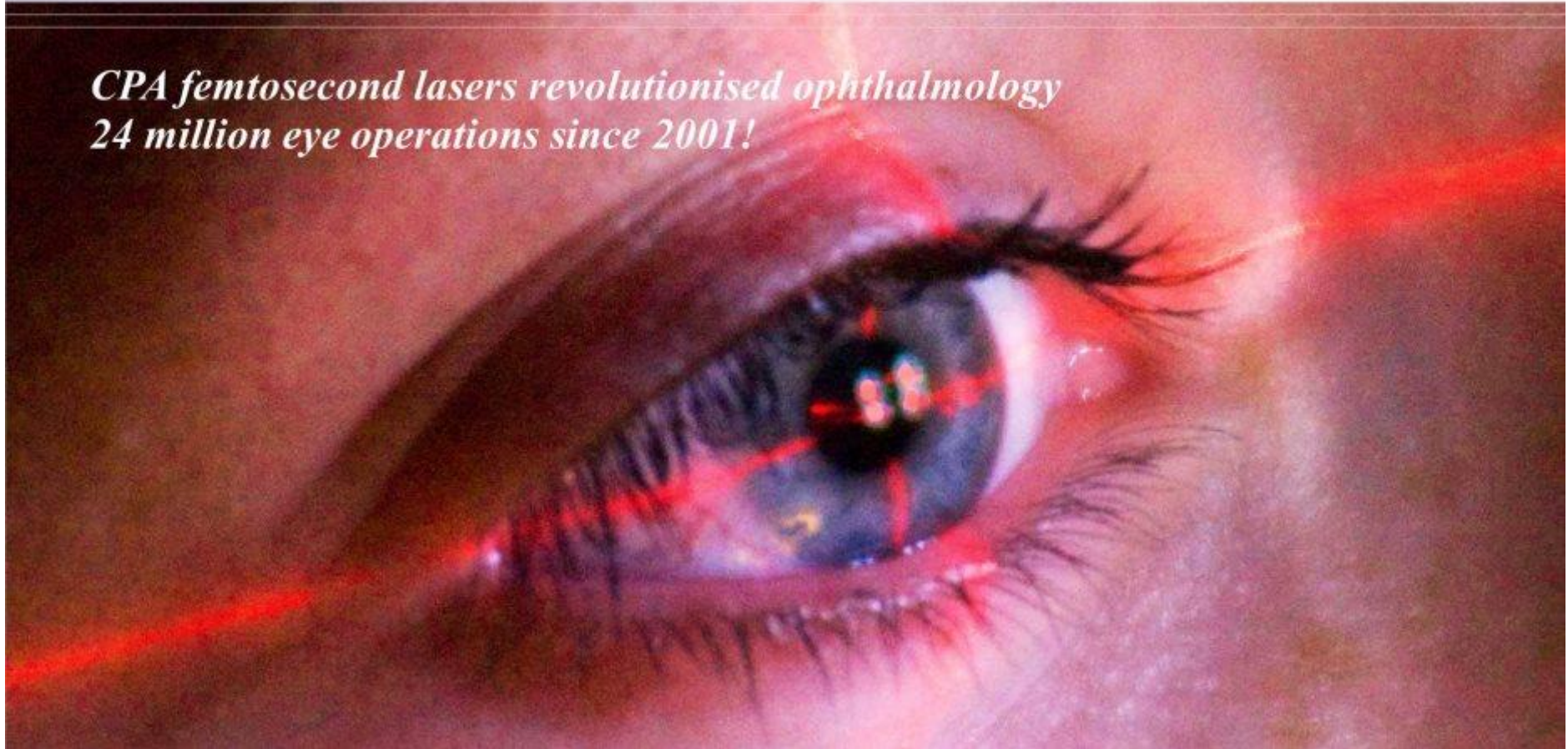


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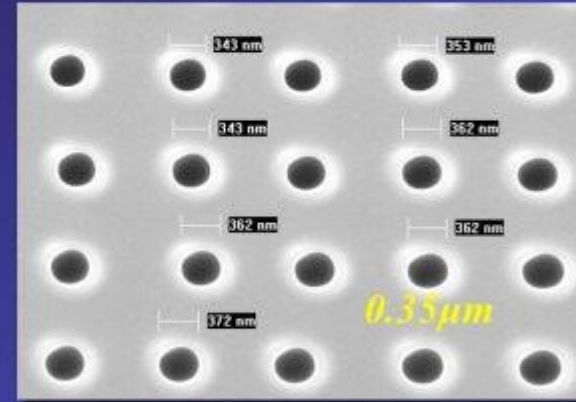
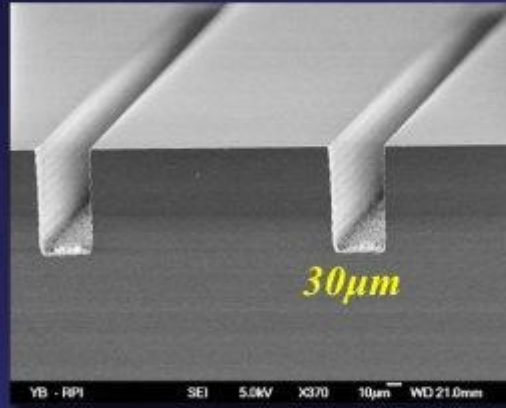
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Giant wakefield acceleration in gas

Tajima et Dawson (1979)

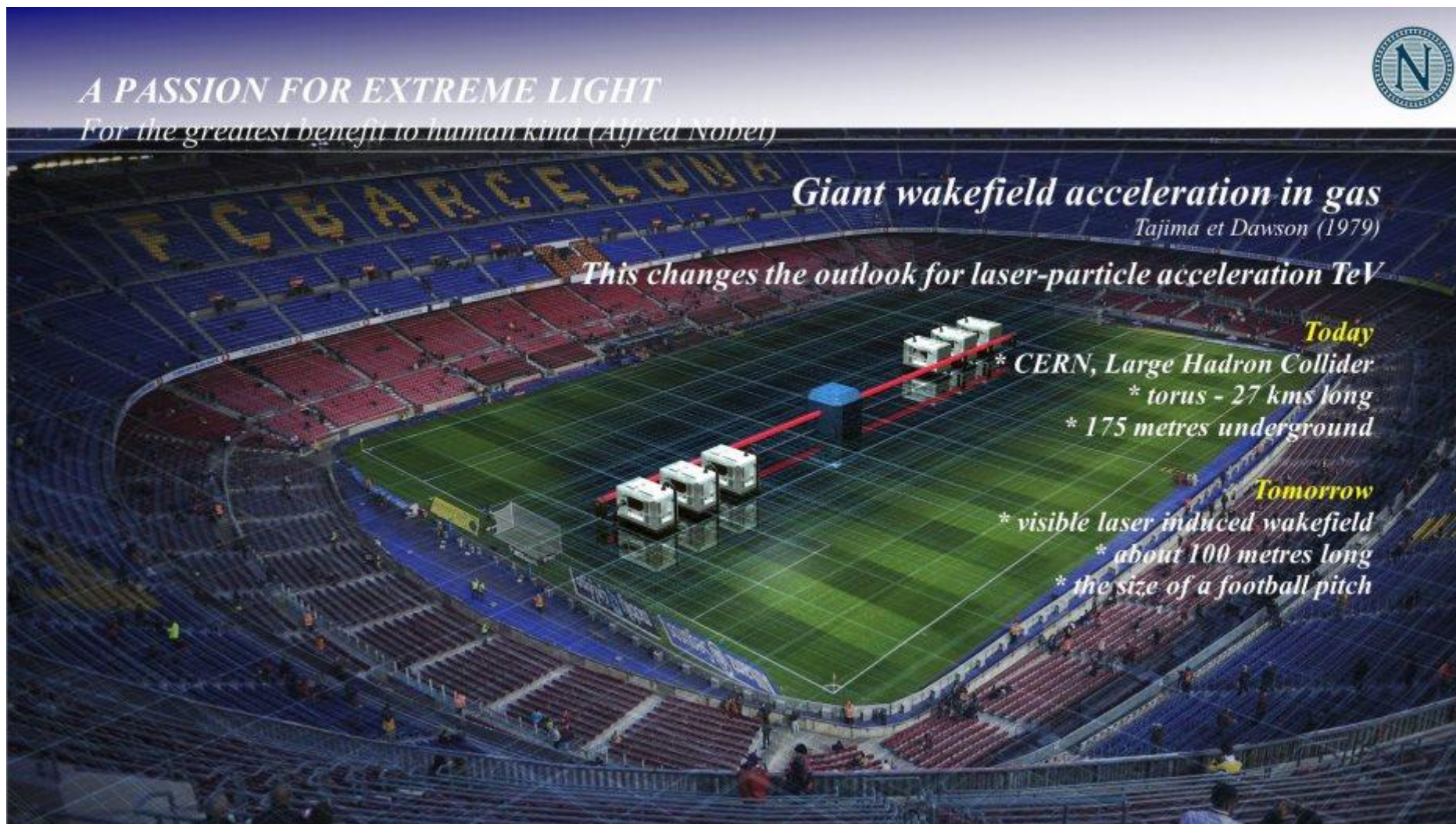
This changes the outlook for laser-particle acceleration TeV

Today

- * CERN, Large Hadron Collider
- * torus - 27 kms long
- * 175 metres underground

Tomorrow

- * visible laser induced wakefield
- * about 100 metres long
- * the size of a football pitch



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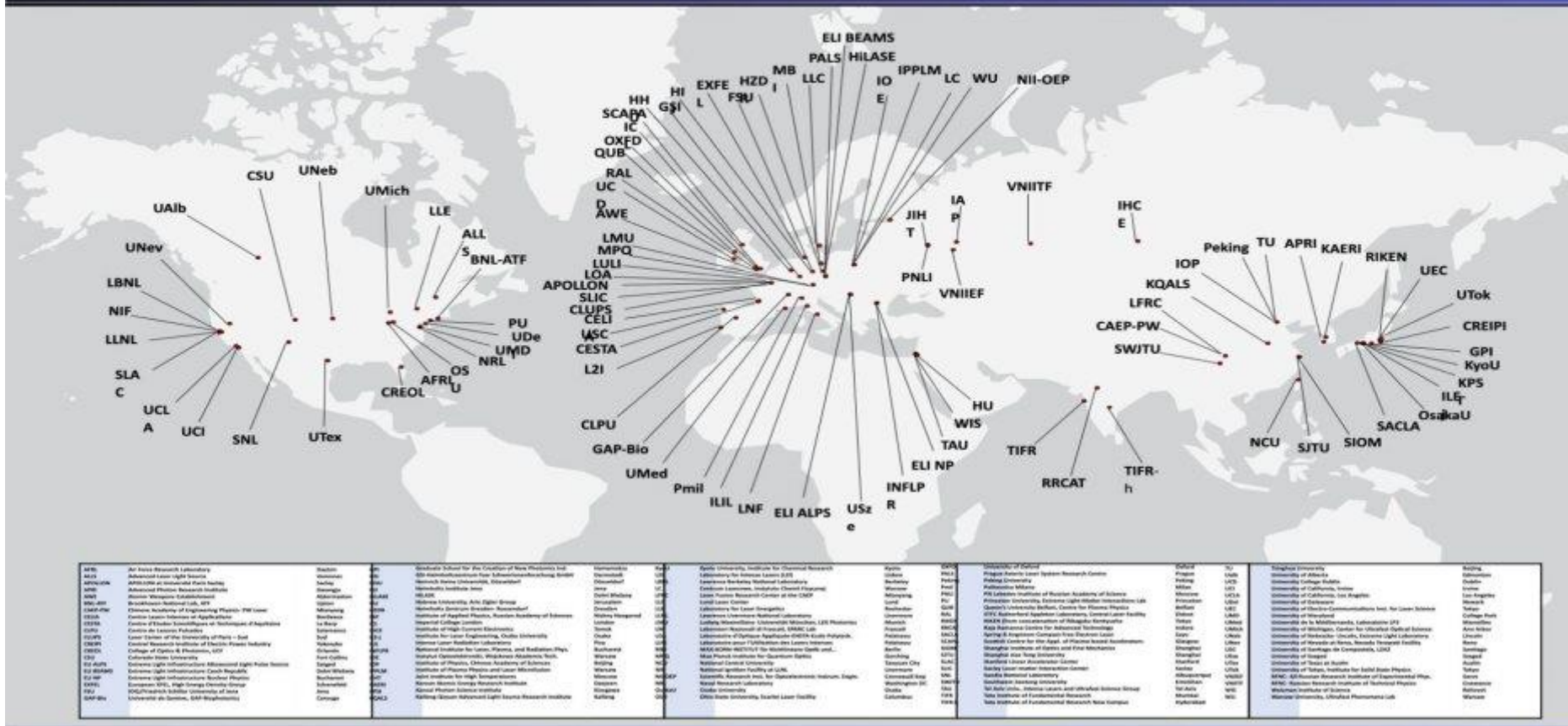
Giant wakefield acceleration in gas and solid

Tajima et Dawson (1979)

A surfer riding down the face of a wave is accelerated by energy of the wave

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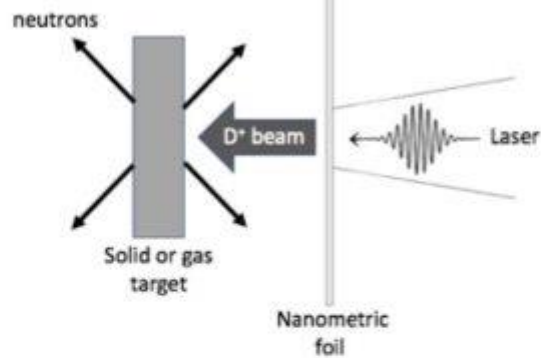
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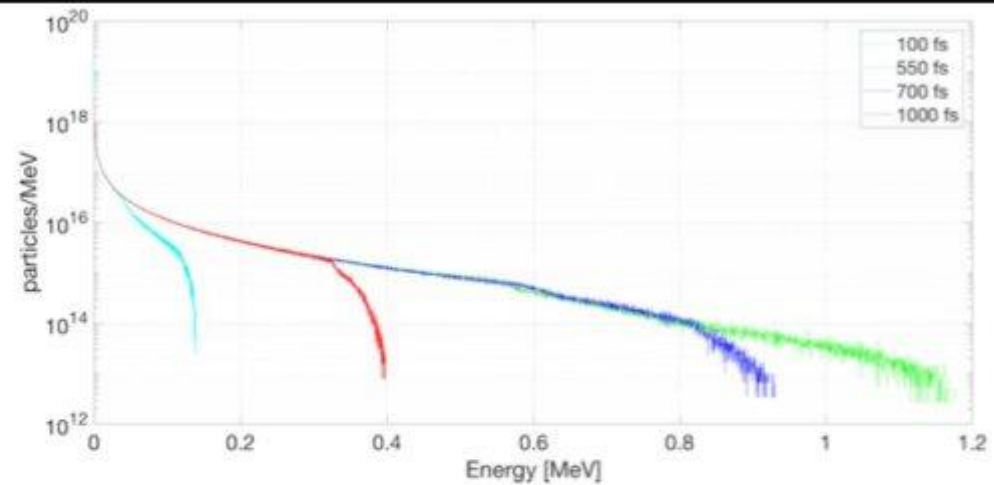


Global petawatt facilities



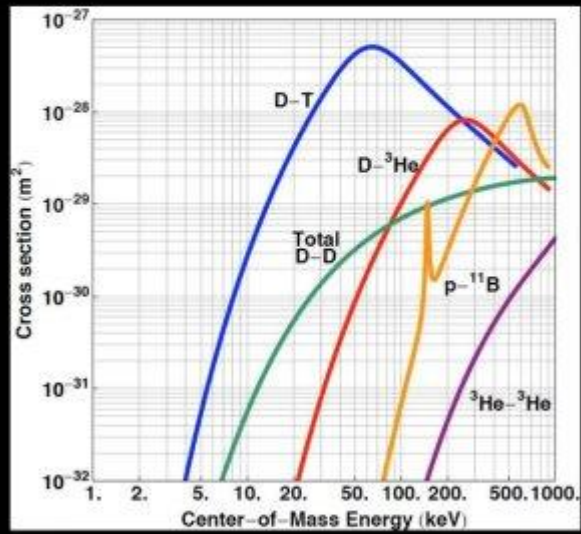


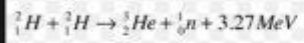
(A)



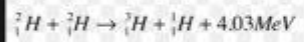
(B)

Figure 3: Neutrons are generated by the laser irradiation of a nanometric deuteron foil, deuteron acceleration and interaction with tritiated solid or gas target. (A) Schematic of neutron generation using laser. (B) D⁺ energy spectrum @ 100 fs, 550 fs, 700 fs and 1000 fs. The average deuteron energy at 550 fs is 100 keV corresponding to ~10% energy efficiency conversion from laser to deuteron.

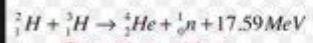




Deuterium-deuterium
Fusion



Deuterium-tritium
Fusion



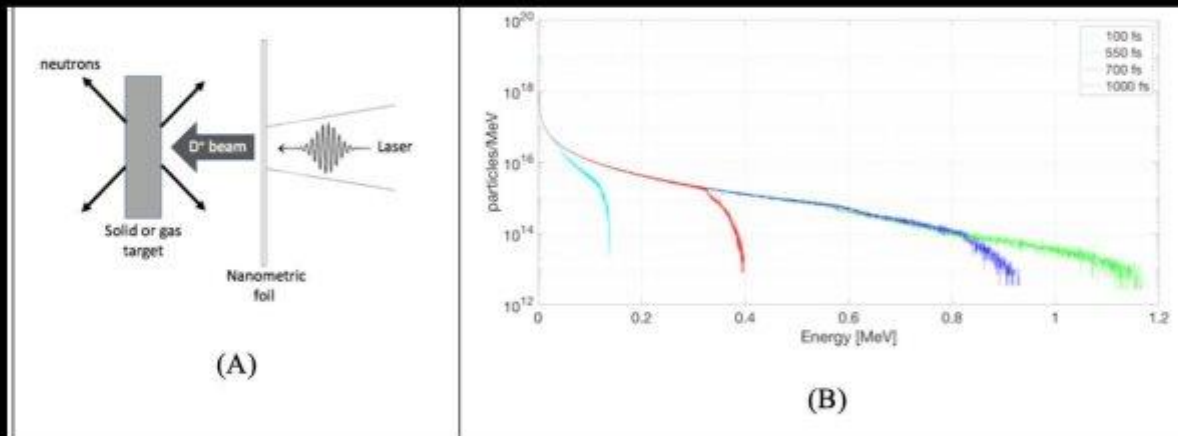


Figure 3: Neutrons are generated by the laser irradiation of a nanometric deuterium foil, deuterium acceleration and interaction with tritiated solid or gas target. (A) Schematic of neutron generation using laser. (B) D⁺ energy spectrum @ 100 fs, 550 fs, 700 fs and 1000 fs. The average deuterium energy at 550 fs is 100 keV corresponding to ~10% energy efficiency conversion from laser to deuterium.

