A PASSION FOR EXTREME LIGHT For the Greatest Benefit of Human Kind

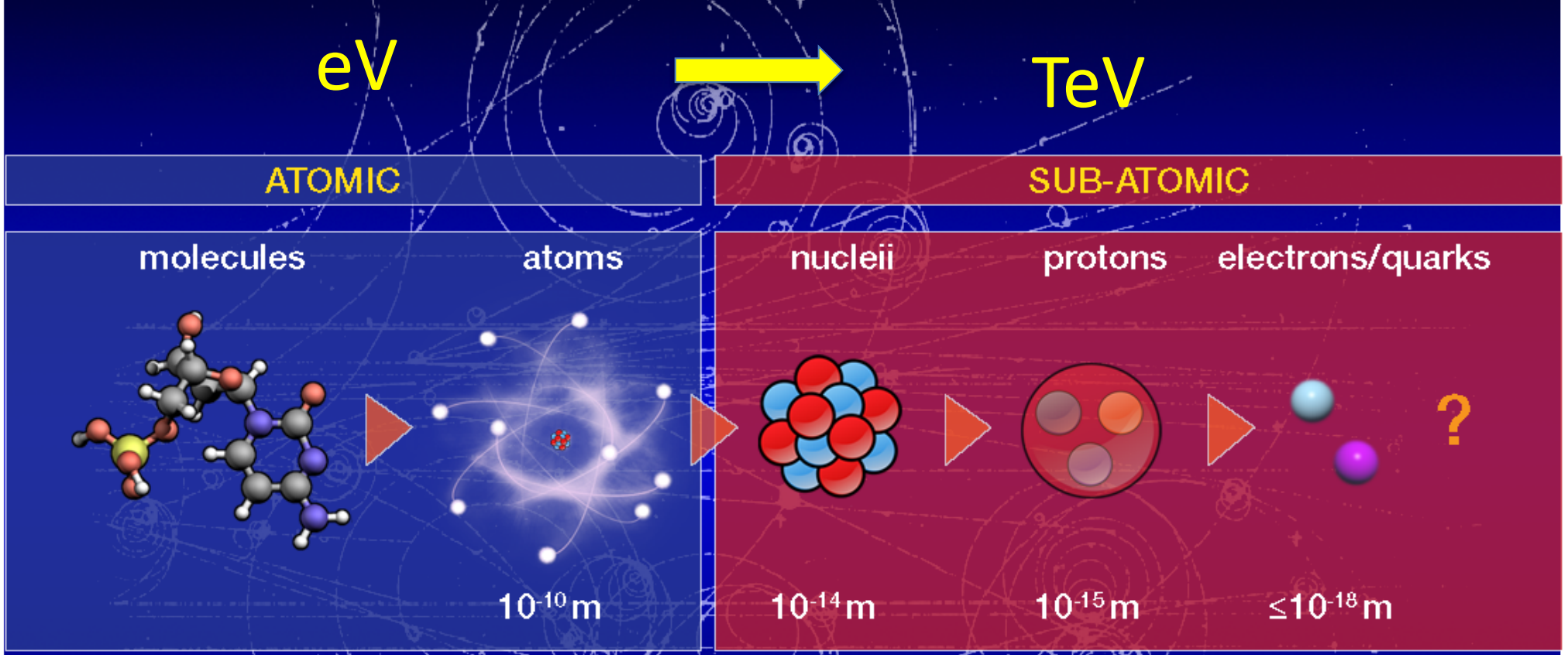
Waves

Presented by

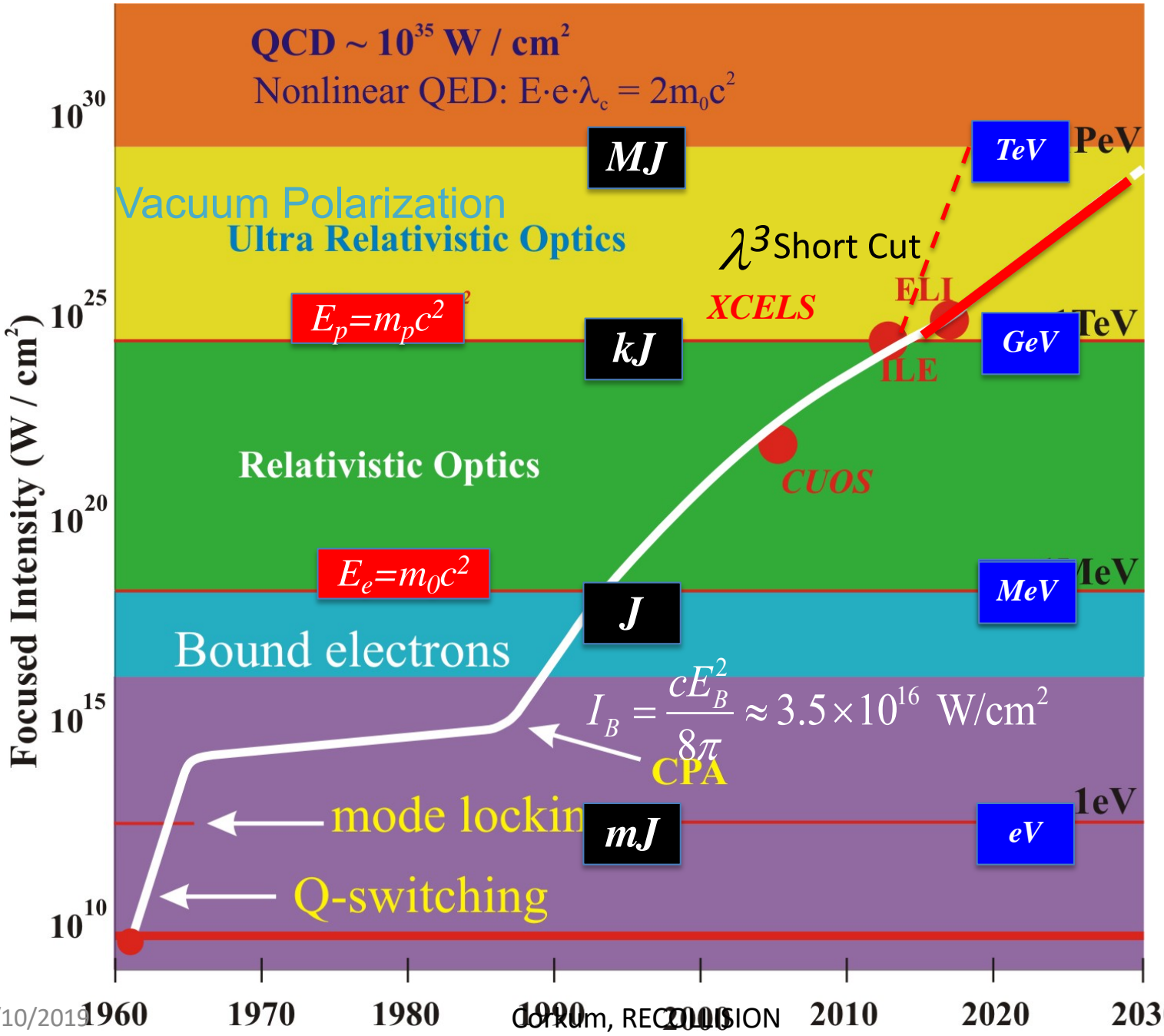
Prof. Gérard Mourou

Nobel Prize for Physics, 2018

Laser Exploration : From Atomic to Sub-Atomic



Extreme Light Road Map and Ultra high Intensity Short Cut



1EW
1Joule in
1 attosec

Extreme Light Infrastructure - ELI

The Largest Civilian Laser Infrastructure

Initiated and Coordinated(PP) by, G. Mourou (EP)

ELI (Delivery Consortium) W. Sandners

Czech Republic

Hungary

Romania

IZEST
International Zeta-Exawatt Science Technology

Corkum, RECOLLISION

International Year of Light 2015

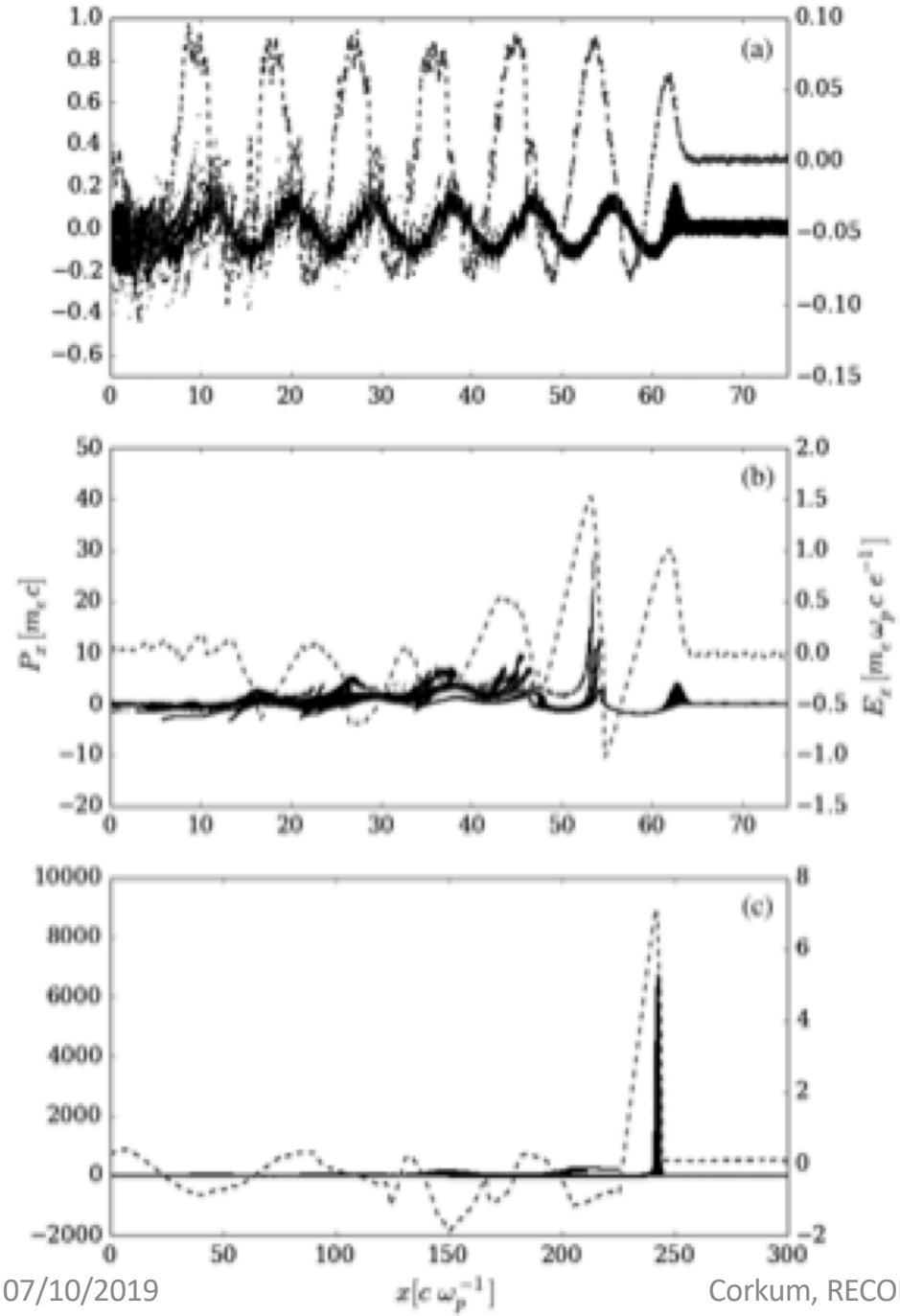
BENEFIT of HIGH ENERGY PULSE COMPRESSION to the SINGLE CYCLE

- The single cycle regime offers great advantages
  Compressing a pulse from N cycles to 1 Provides:

  ✓ an increase of peak power by N
  ✓ an increase of the ponderomotive force by N^2
  ✓ A quieter Interaction with the plasma

For the same ponderomotive force i.e accelerating gradient, it leads to a laser size and cost reduced by a factor N^2.

Multi-Cycle vs Single Cycle



Laser Wake Field LWA
And
Single Cycle (BWA)

BWA BWA Bow W Acceleration

The longitudinal electron acceleration in highly relativistic regime as a function of a_0. The longitudinal P_z momentum gain with relativistic waves, as a function of relativistic wave amplitude: phase-space diagrams showing the effect of electromagnetic waves of increasing intensity on plasmas of the same mass ratios ($m_i / m_e = 1836$) (a) $a_0 = 0.4$, (b) $a_0 = 2$, and (c) $a_0 = 60$. The dotted lines represent the electric field in the longitudinal direction. These three cases most clearly illustrate the differences between the sub-relativistic (WA only), slightly relativistic (WA and BWA), and ultra-relativistic (BWA only) regimes. In the slightly relativistic regime, the figure shows the wave breakings which destroy the wakefield structure, allowing the BWA to become the dominant acceleration as a_0 increases. From (Lau et al. 2015).

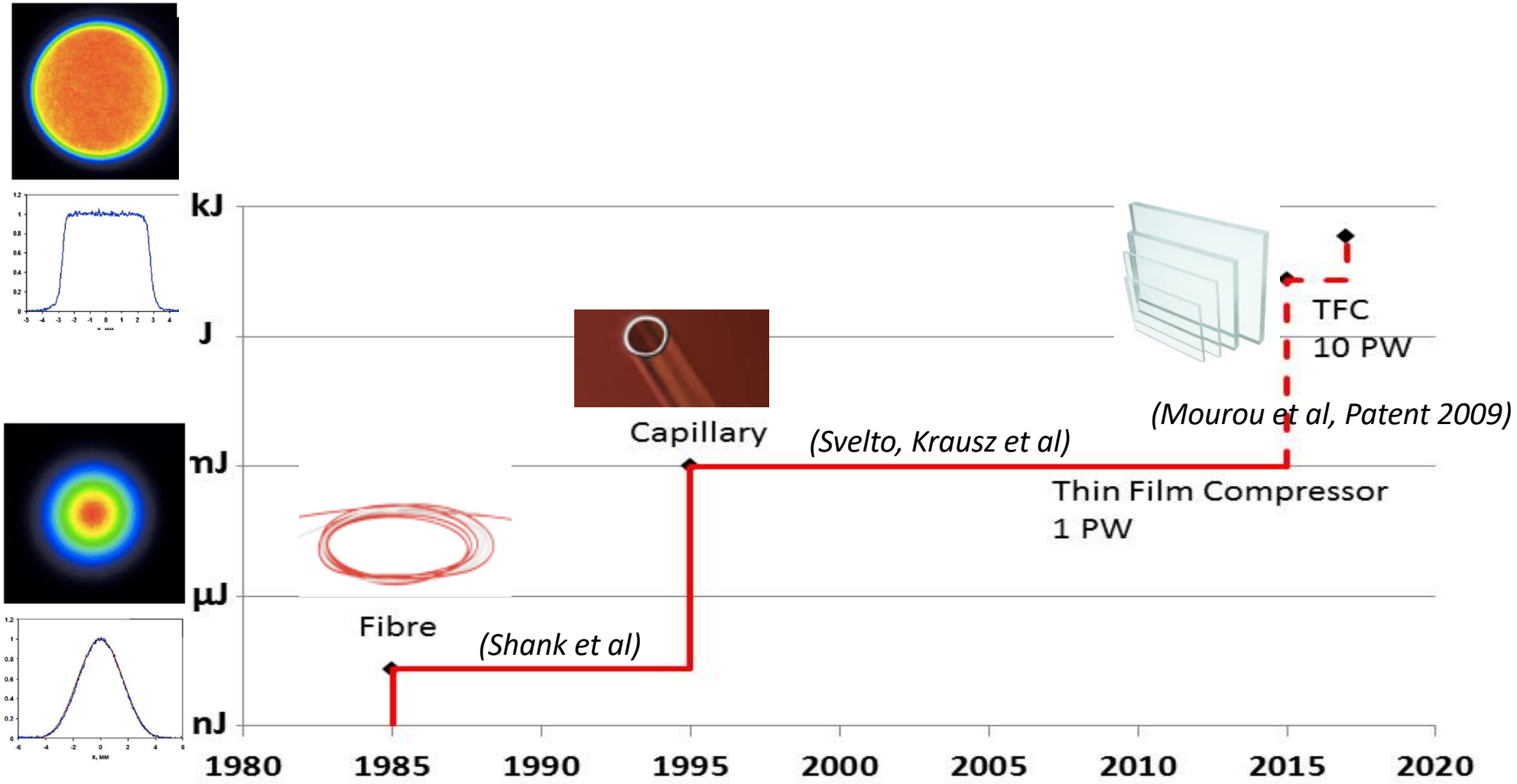
Compression High Energy Pulse to the Single Cycle: From Visible to X-Ray

Two steps

1. Compression in the Visible: SPM-GVD in Glass

2. Compression in the X-Ray: Relativistic Mirror

Single Cycle Pulse Compression In the Visible

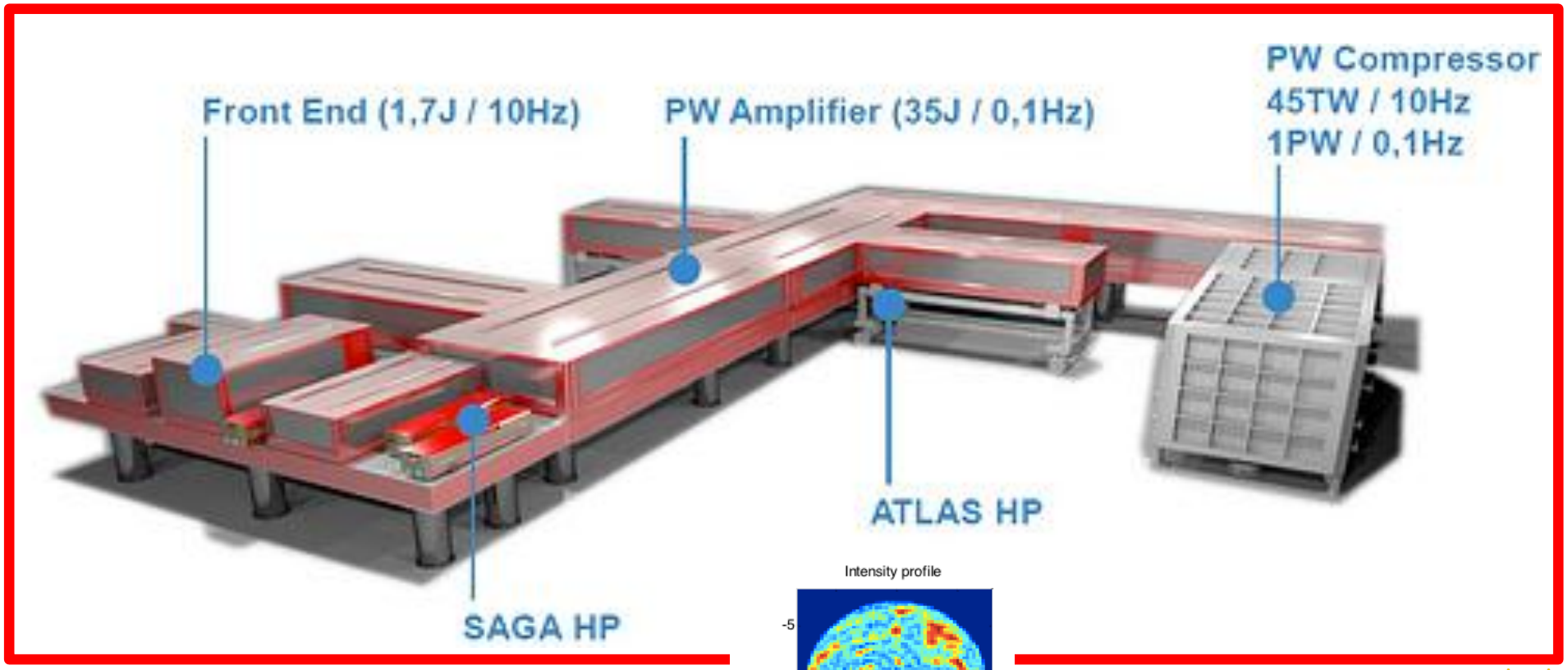


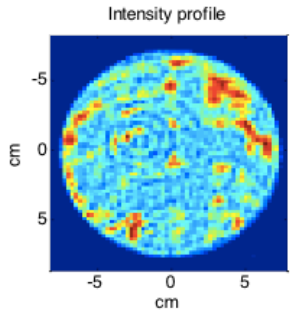
Gérard Mourou, Gilles Cheriaux, Christophe Radier,Device for generating a short duration laser pulse US 20110299152 A1

Petawatt Laser Provides

A 10-1000J Uniform wave front in

Phase and Amplitude





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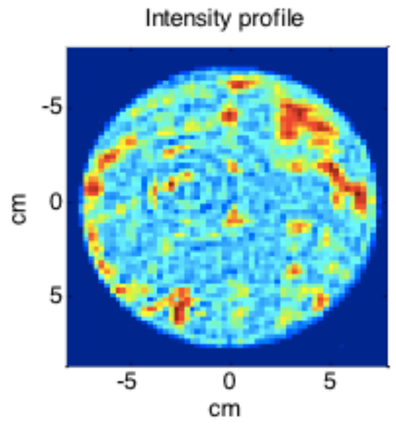
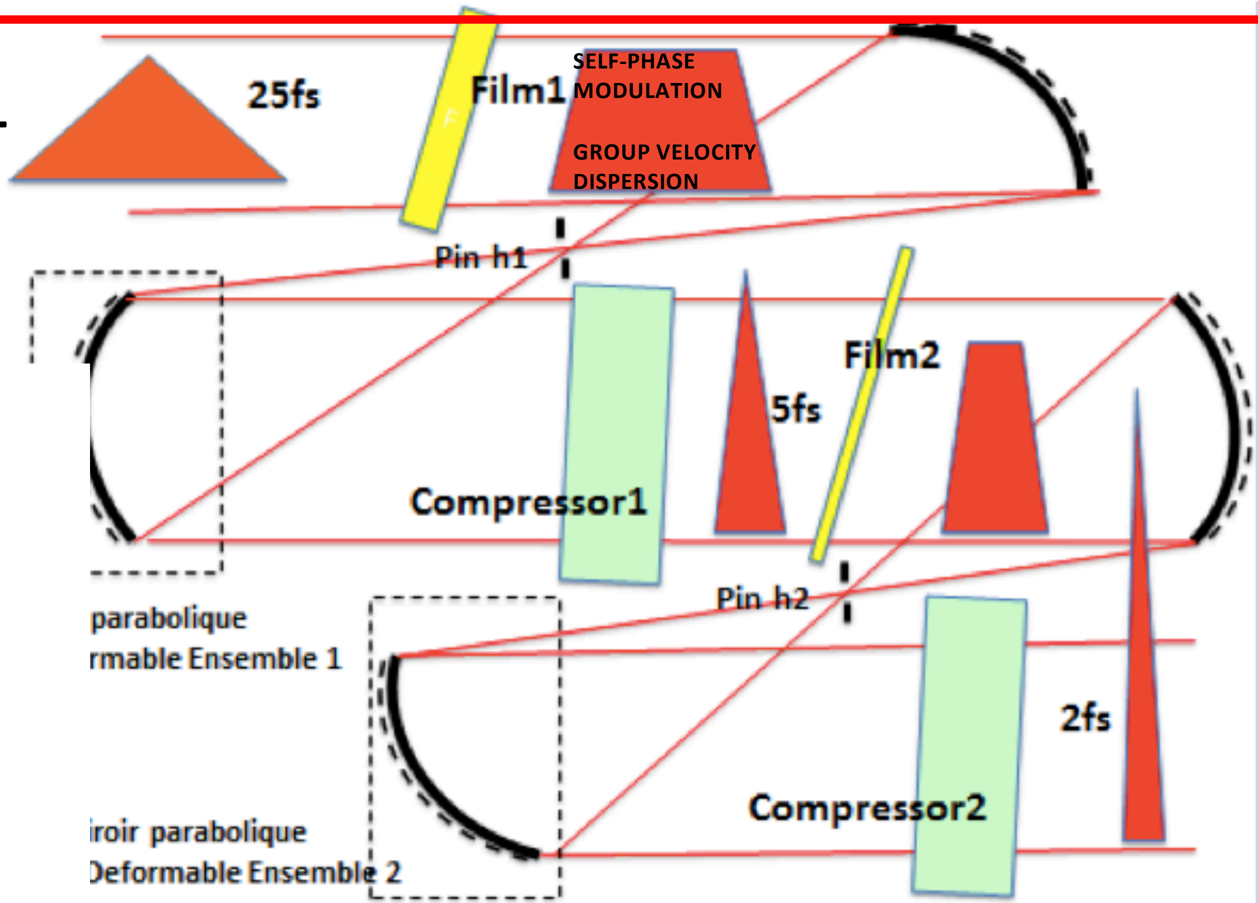
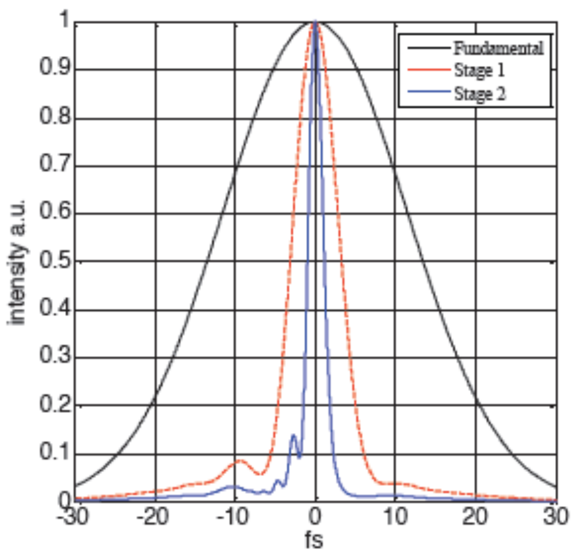
Single Cycle Thin Film Compressor TFC



CETAL





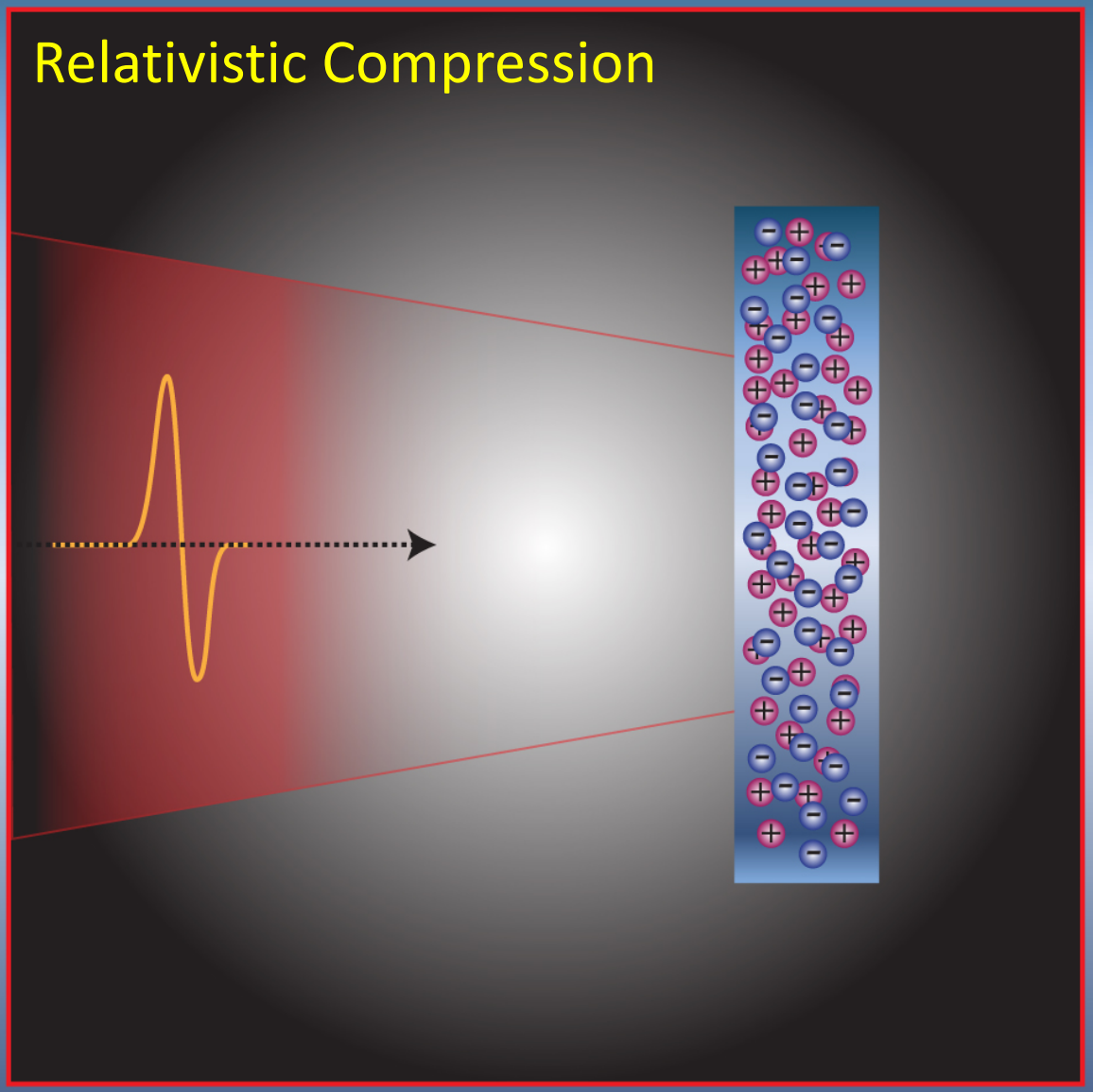
G. Mourou, S. Mironov, E. Khazanov and A. Sergeev, Single cycle Physics , Eur. Phys. J. Special Topics, 223, 1181(2014)
A.A. Voronin, A.M. Zheltikov, T. Ditmire, B. Rus and G. Korn Optics. Com. 2011
G. Mourou, G. Cheriaux, C. Radier Patent 2009

Relativistic Compression in in the λ^3 Regime

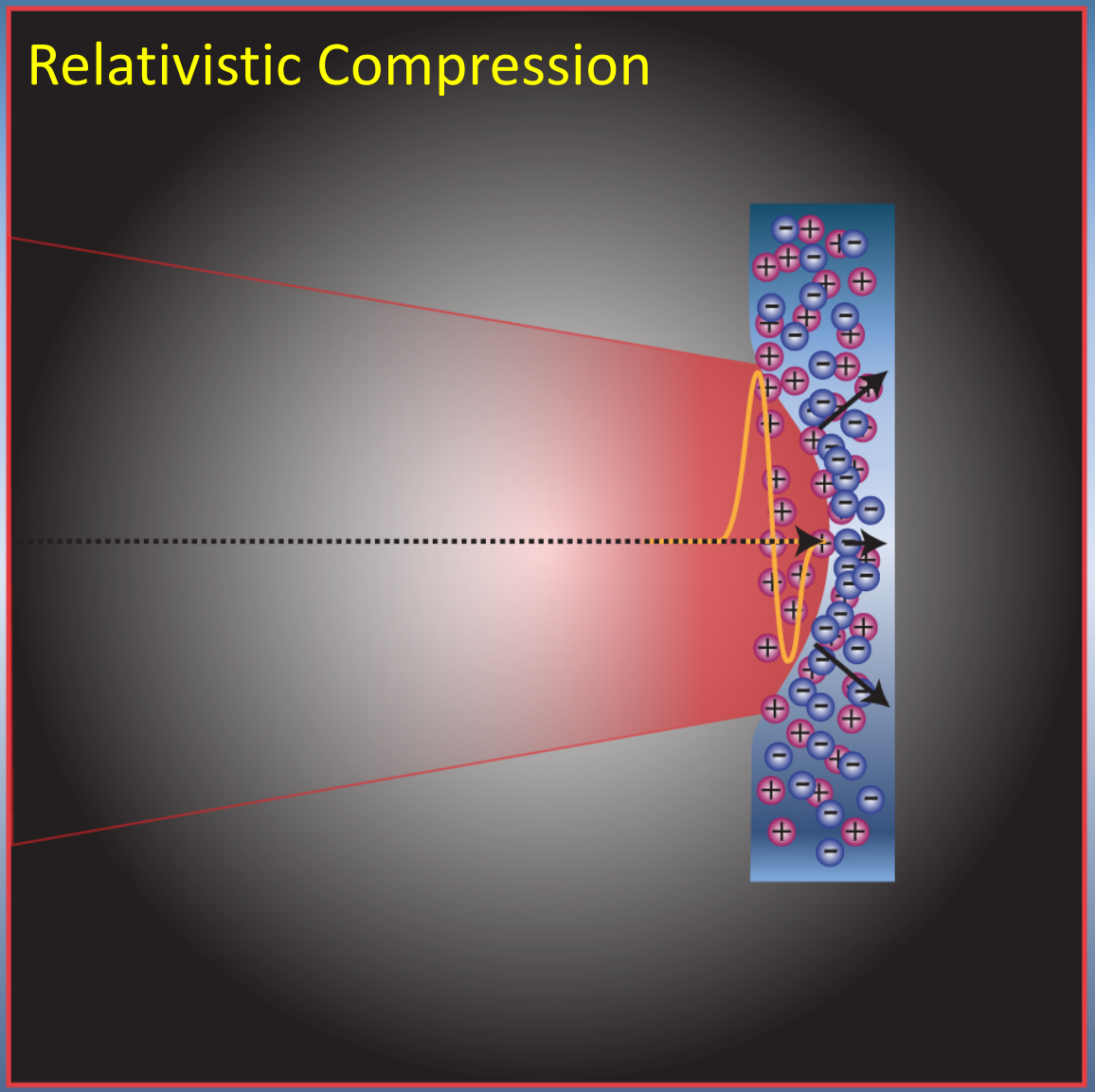
Scalable Isolated Attosecond X-ray Pulse

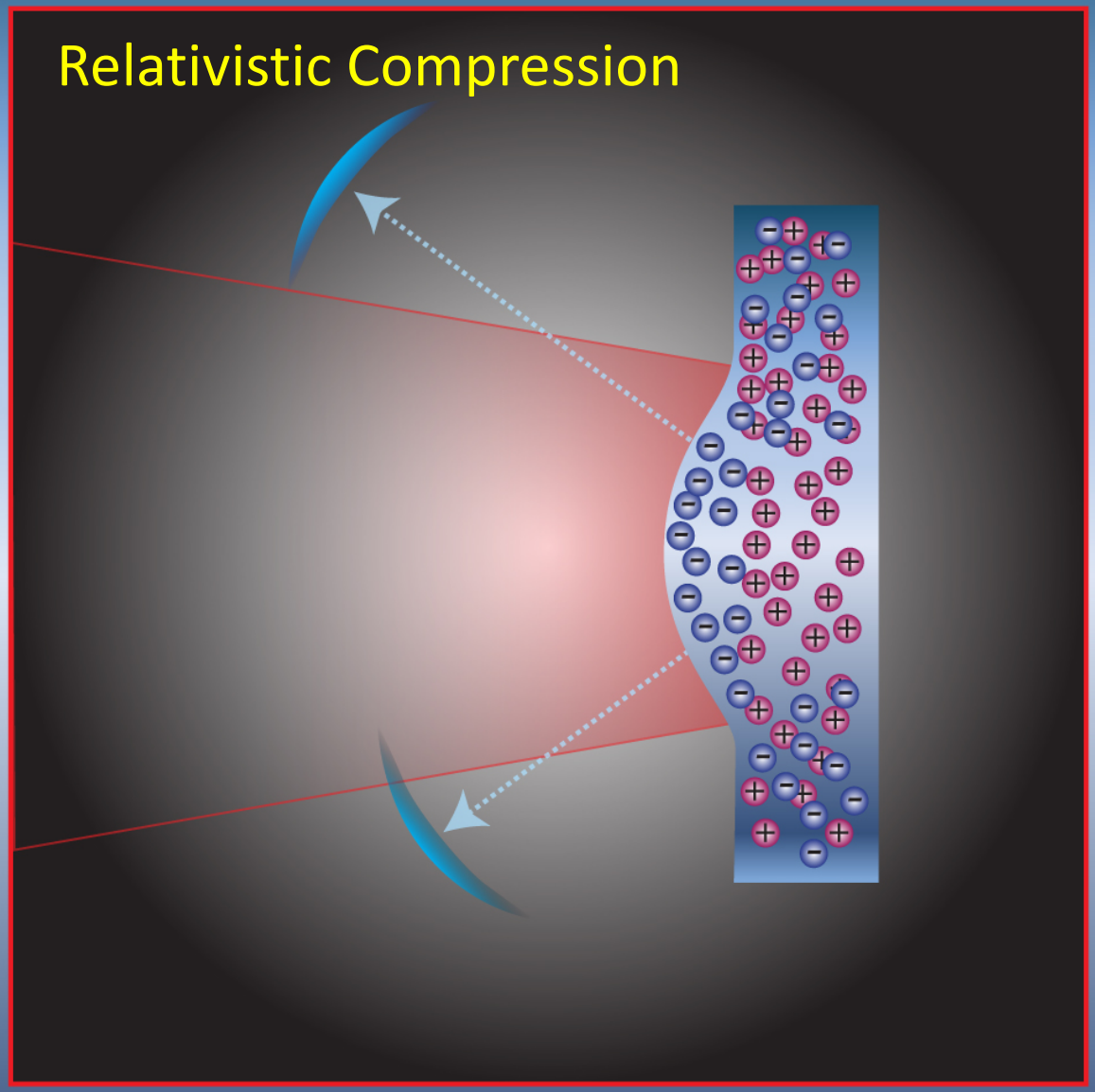
N. M. Naumova, J. A. Nees, I. V. Sokolov, B. Hou, and G. A. Mourou,
Relativistic generation
of isolated attosecond pulses in a λ^3 focal volume, Phys. Rev. Lett. 92, 063902-1 (2004).

Relativistic Compression



Relativistic Compression




Relativistic Compression

Scalable Isolated Attosecond Pulses

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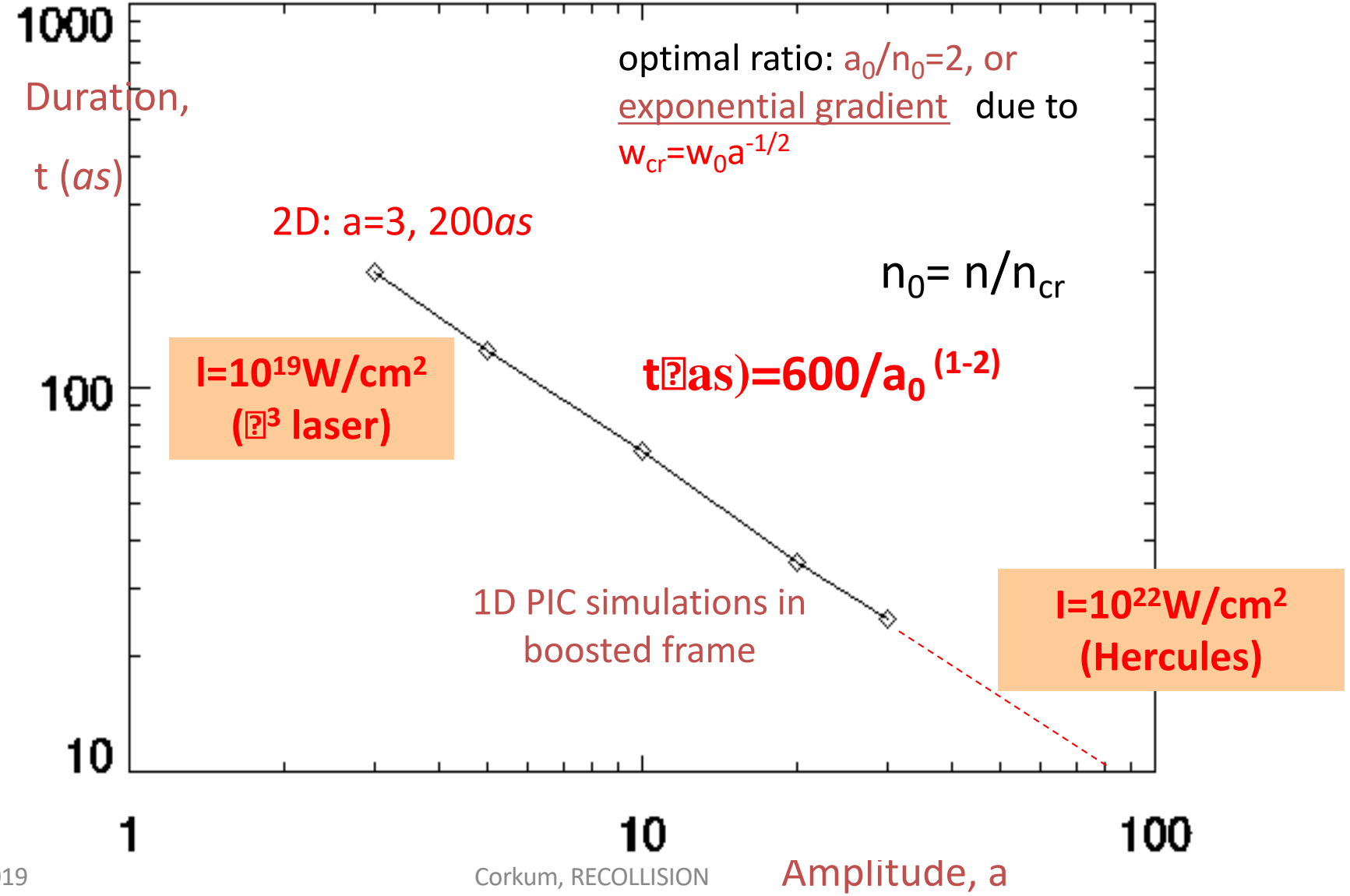
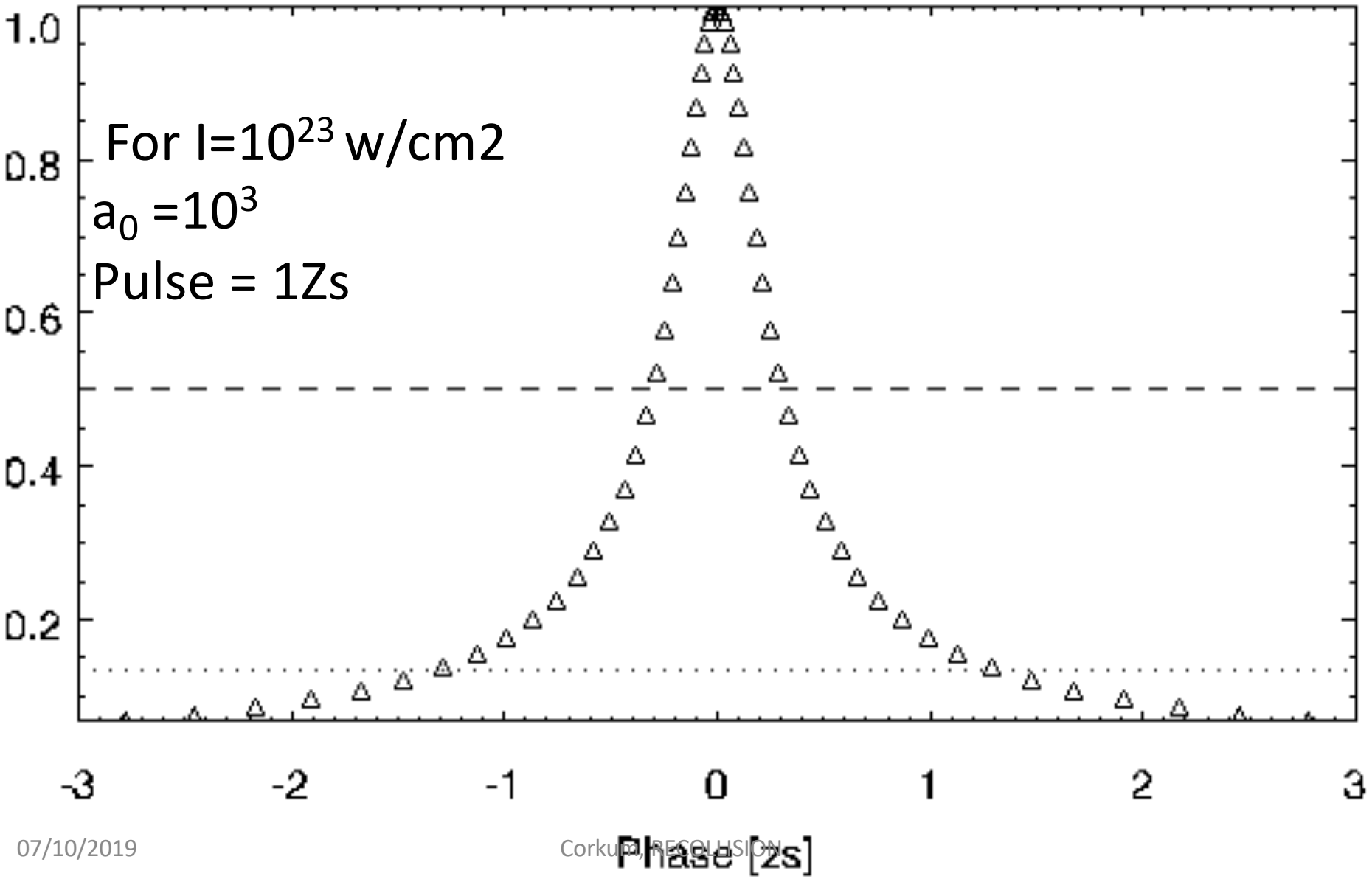


Zeptosecond pulses, (N. Naumova, I. Sokolov, G. Mourou)
(Preliminary Result)



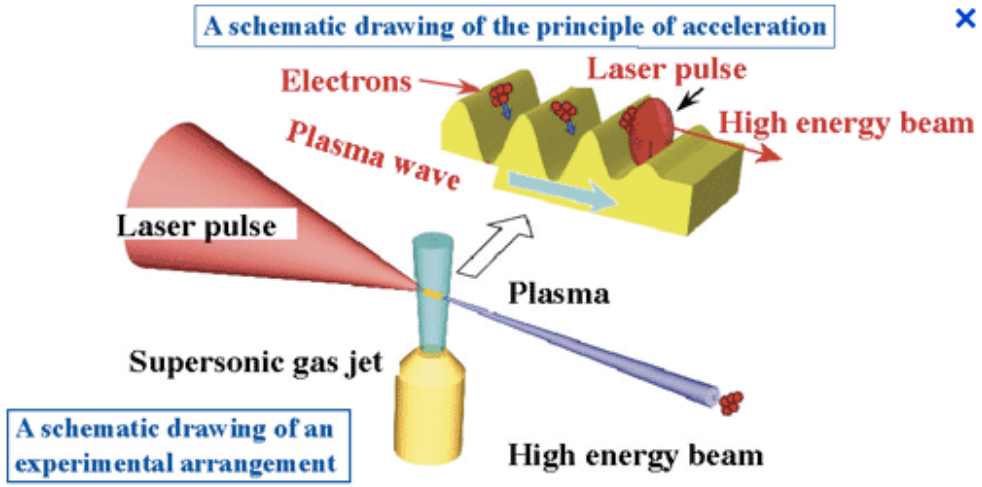
But a zeptosecond pulse is also:

1. 1J in a Zs (10^{-21}s) is a Zettawatt Zw (10^{21}W)
2. A Zs (10^{-21}s) is a 1MeV Coherent Gamma-ray
3. Free Electron laser with high energy joule and high temporal resolution
4. Giant Laser Acceleration in solid: TeV/cm (CERN on a Dime) towards PeV
5. Zw over λ^2 spot size is 10^{29} W/cm^2 Schwinger Intensity: light turns into matter and antimatter

Low Hanging Fruits
Electron Wake Field Acceleration

Giant Wake Field Acceleration in Gas and Solid

Femtosecond Visible Light Driver in Gas ***Tajima et Dawson 1979***



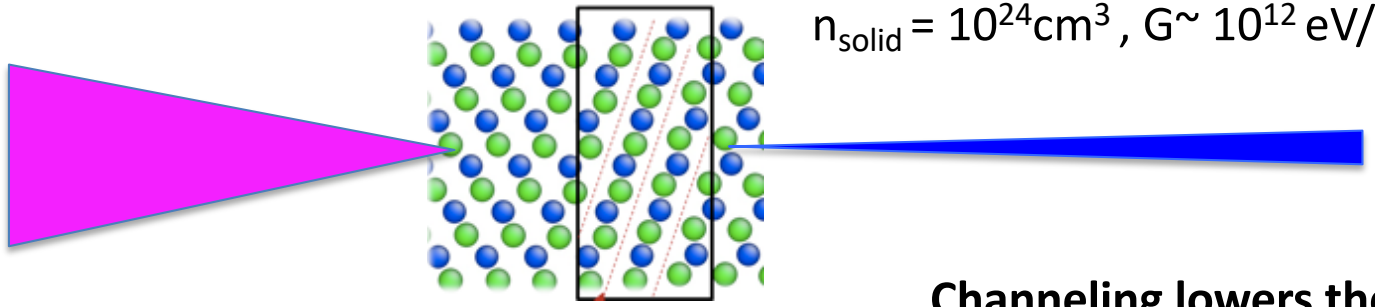
Plasma Acceleration Energy Gain

$G \alpha n^{1/2}$ eV/cm

1eV light $n_c \sim 10^{21} cm^{-3}$

$n_{gas} = 10^{18} cm^{-3}$, $G \sim 10^{9}$, GeV/cm

Atto-zepto, X-ray Driver, Solid, ***Tajima et Cavenago 1987***



$n_{solid} = 10^{24} cm^{3}$, $G \sim 10^{12}$ eV/cm, TeVcm

Drive pulse X-Ray, 600zs
+ as electron pulse

Channeling lowers the emittance
Valid for electrons, muons, heavy ions

Laser-Wake-Field Acceleration
Gas/NIR vs Solid/ X-Ray

Serendipity at its best

$n_{c\ \text{for X-ray}}\ 10^{29}\ /cm^3$

Energy Gain $E=a_0^2 m_o c^2 (n_c/n_e)$

In the visible $n_c = 10^{21}/cm^3$ Low gaz density

In the X-ray, $n_c = 10^{29}/cm^3$ Solid density

10keV

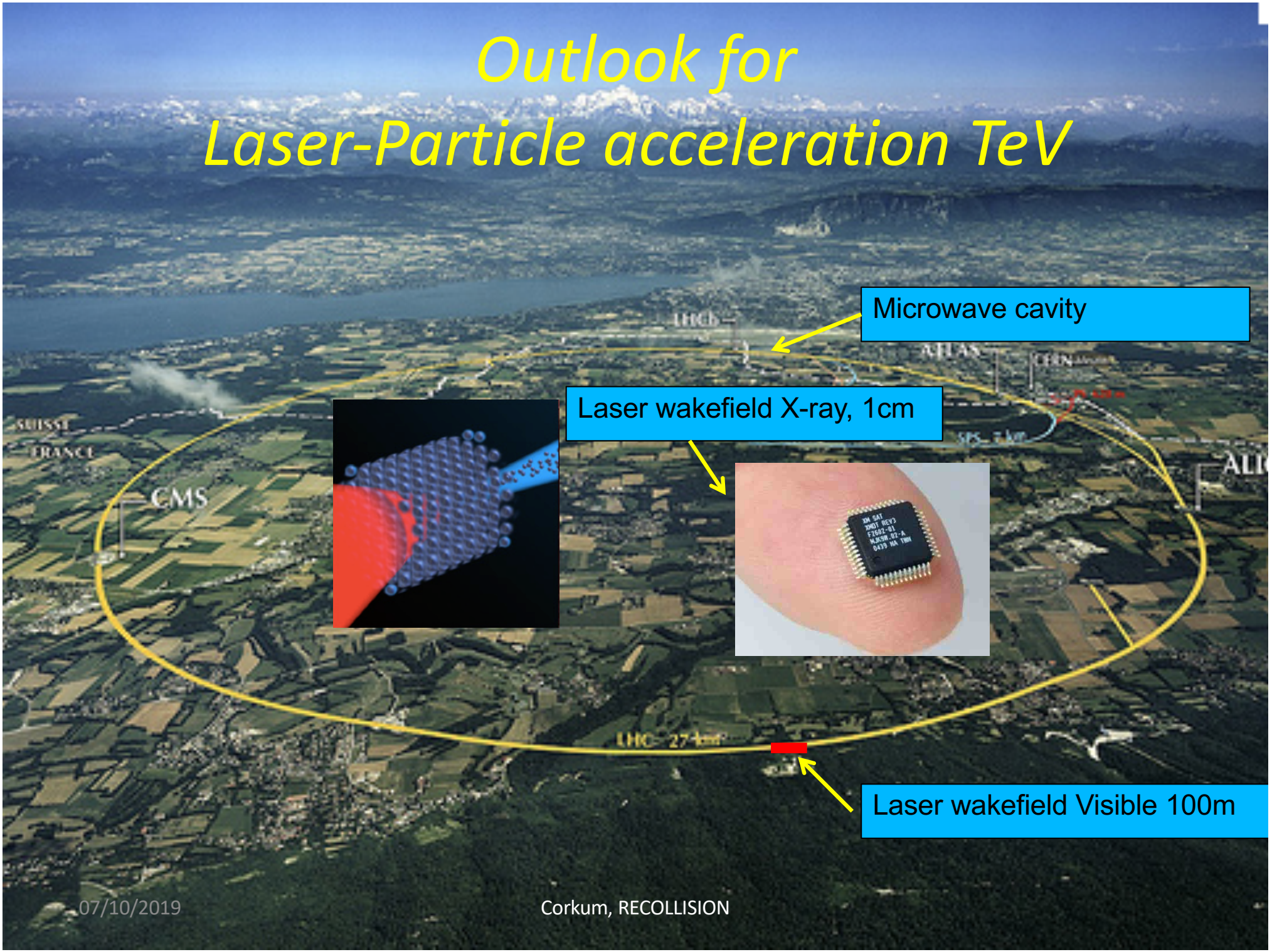
n_{solid} $10^{23}\ /cm^3$

$n_{c\ light}$ $10^{21}\ /cm^3$

n_e $10^{18}\ /cm^3$

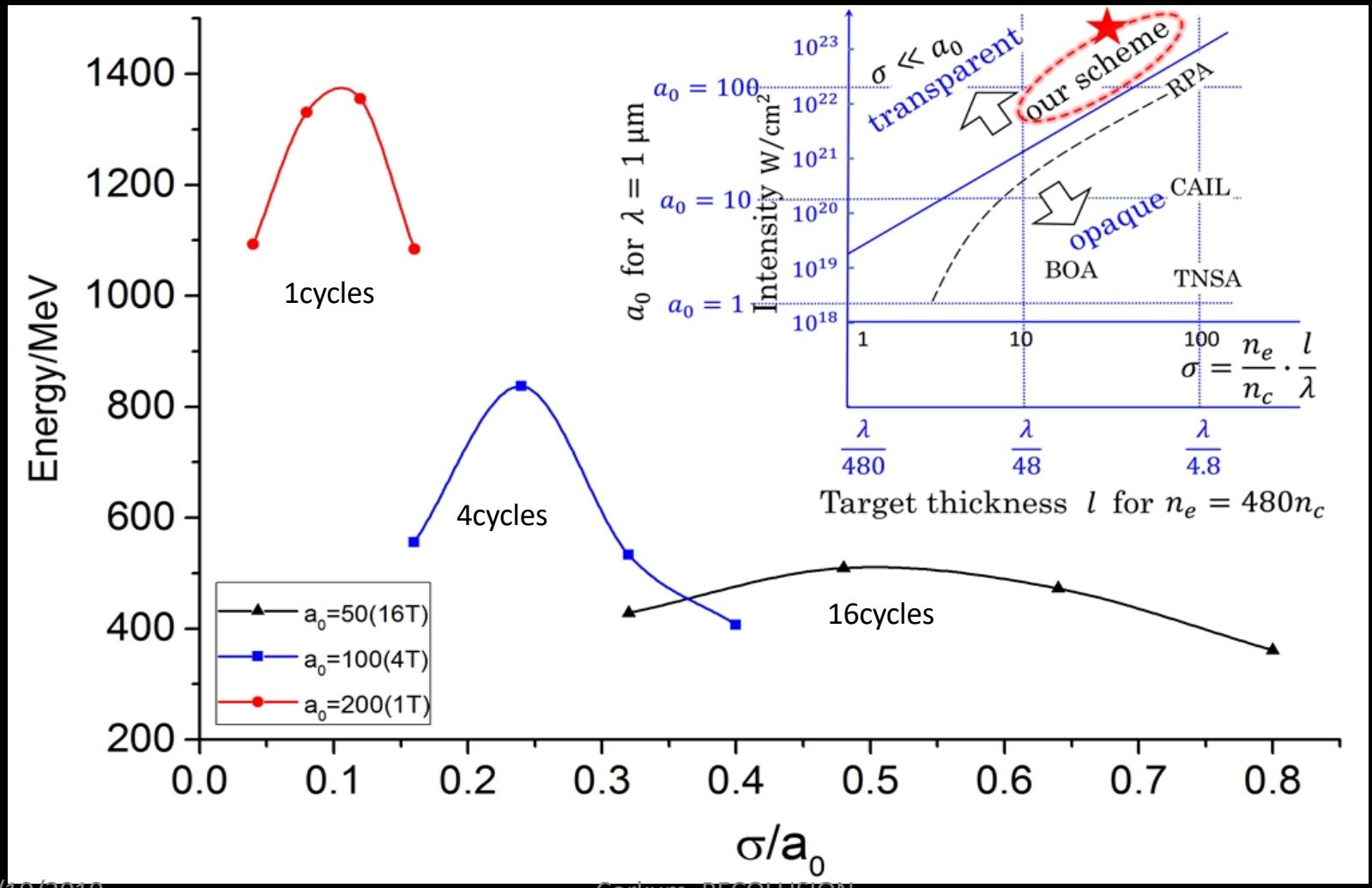
1eV

Outlook for Laser-Particle acceleration TeV



Low Hanging Fruits
Proton Generation

Applications of Single Cycle to Proton Generation vs a_0



Single Cycle Extreme Light Grand Challenges: Scientific and Societal Applications

Scientific Applications

Laser Astrophysics and Cosmology

Polarization of Vacuum, Materialization of Light

Beyond the Standard Model

Higgs Factory

Dark Matter

Societal Applications

Transmutation of Nuclear Waste

Under Critical Reactor

Nuclear Pharmacology

Proton Therapy

IZEST International Zeta-Exawatt Science Technology

International Year of Light 2015

Conclusion

The field of Ultrashort and Ultra High intensity is on an irrestible ascent from eV to PeV.

and

‘The Best is yet to come’.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AKADEMIEN
THE ROYAL SWEDISH ACADEMY OF SCIENCES
"...har till uppgift att främja vetenskaperna och stärka deras inflytande i samhället."
"...has as its aim to promote the sciences and strengthen their influence in society."
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A PASSION FOR EXTREME LIGHT

For the greatest benefit to human kind (Alfred Nobel)

Merci de votre attention

Science of High Energy, Single-Cycled Laser

JONATHAN WHEELER
DER-IZEST, Ecole Polytechnique,
Route de Saclay, FR-91128, Palaiseau, France
ELI-NP, Horia Hulubei - National Institute for Physics and Nuclear Engineering,
30 Reactorului Street, RO-077125, Bucharest-Magurele, Romania
jonathan.wheeler@polytechnique.edu
GÉRARD MOUROU
DER-IZEST, Ecole Polytechnique,
Route de Saclay, FR-91128, Palaiseau, France
dir-izest@polytechnique.edu
TOSHIKI TAJIMA
Department of Physics and Astronomy, University of California, Irvine,
4164 Frederick Reines Hall, Irvine, California, USA
ttajima@uci

Review of Accelerator of science and Technology

A PASSION FOR EXTREME LIGHT

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The Pulse Duration-Intensity Conjecture

G.A. Mourou and T. Tajima, "More intense Shorter Pulse",

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