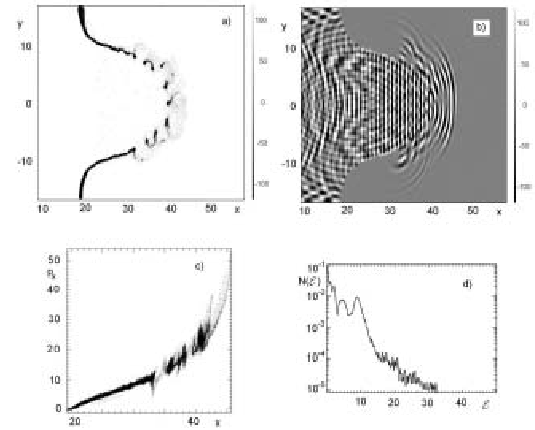
3rd International Conference on Frontiers of Plasma Physics and Technology

Summary by
David Neely

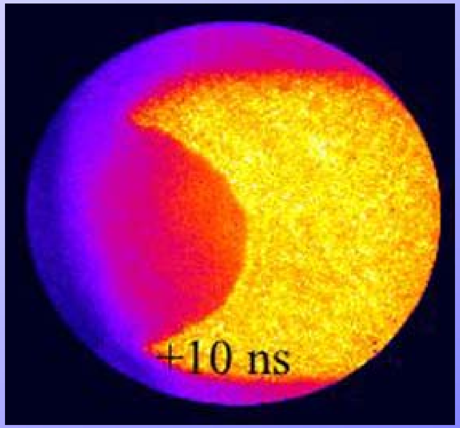
Laser Plasma interactions (a very brief overview)

- **Reaching new areas of study**
  - **Astrophysics, EOS, Jets, scaling, …..**
- **Fast Ignition field**
  - **Laser smoothing, plasma smoothing, cone interactions**
- **Ultra-high intensity interactions**
- **Simulations**
  - **QED, scattering, transport, PIC, instabilities**
- **Laser driven electron and ion acceleration**
- **Secondary sources**
- **Interaction physics**
  - **Instabilities, New amplifer- Raman**
  - **Proton probing B-field and charge evolution**

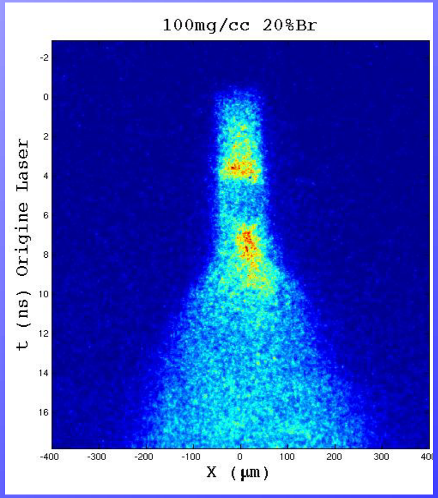


NEW LABORATORY ASTROPHYSICS Experiments at LULI

Radiative shocks is a good example of coupling between hydrodynamics & radiation. Present results allowed to benchmark 2D ICF codes.
Future work will achieve higher radiative regime
Comparison with astro codes

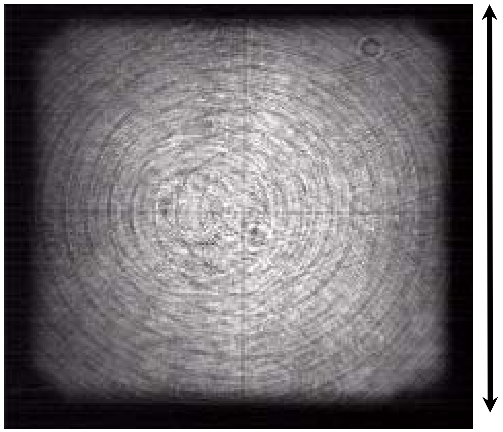


We explore some new design to generate high mach number plasma jets. Present results showed already good similarities with astrophysical objects.
Future work , already under consideration, is to get these jets to interact with ambient medium



New Facilities　FIREX

ILE OSAKA



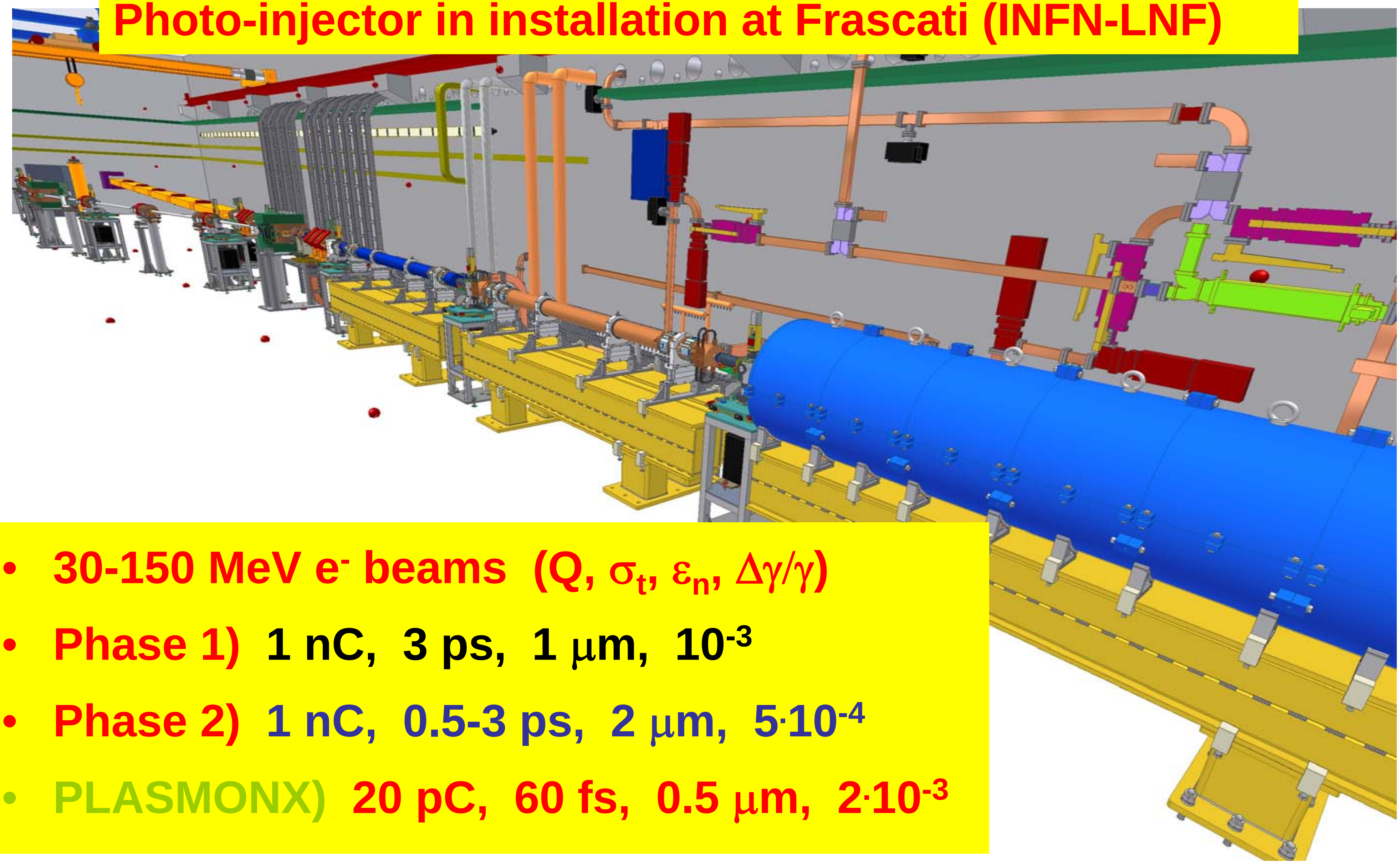
32.5 cm

06.5.19　3.6 kJ/1 beam(narrow band)
(Full beam equivalent =14.4 kJ)
06.7　　2kJ/1beam(broad band)

PLASMON X

SPARC

Photo-injector in installation at Frascati (INFN-LNF)



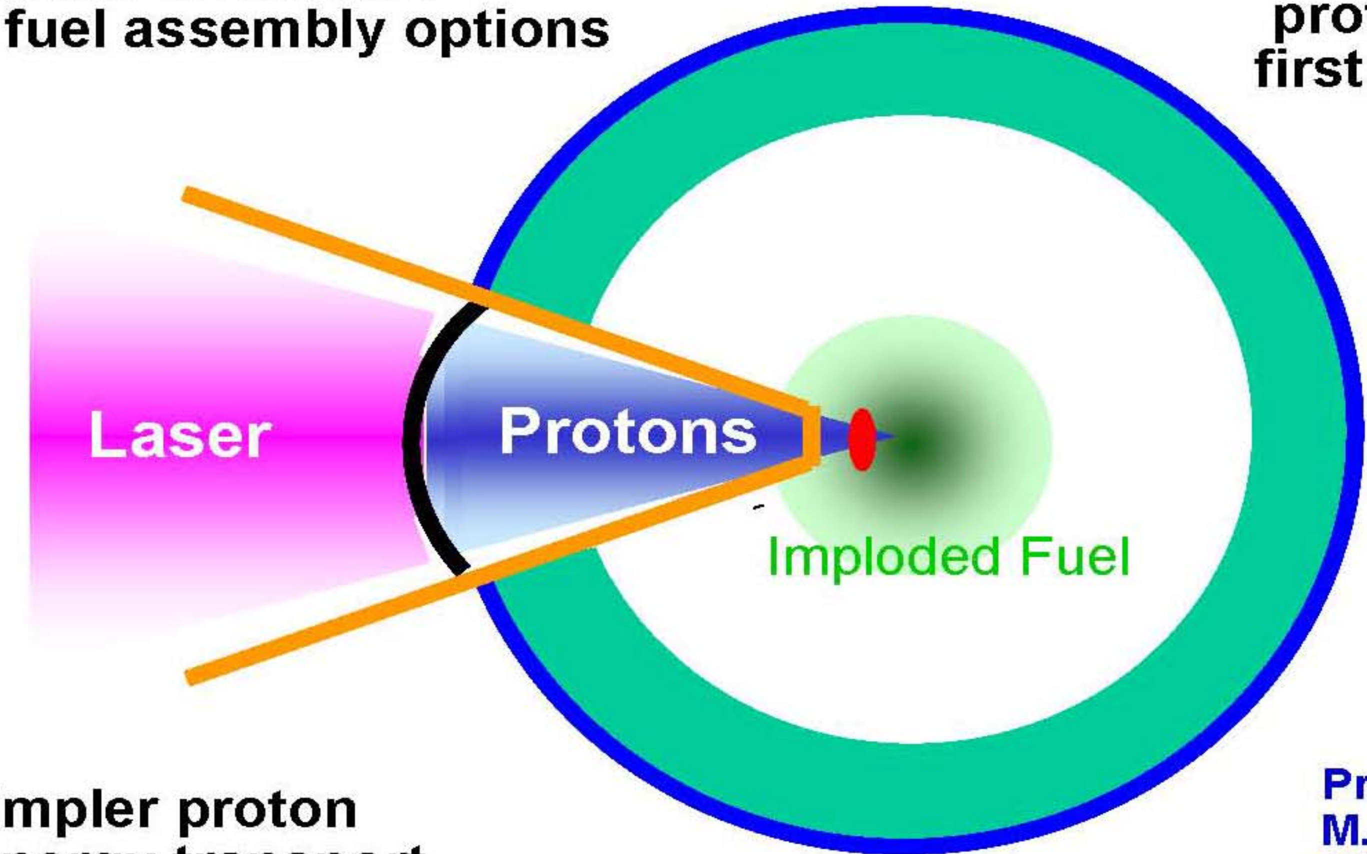
- 30-150 MeV e^- beams (Q, σ_t, ε_n, $\Delta\gamma/\gamma$)
- Phase 1) 1 nC, 3 ps, 1 μm, 10^{-3}
- Phase 2) 1 nC, 0.5-3 ps, 2 μm, $5 \cdot 10^{-4}$
- PLASMONX) 20 pC, 60 fs, 0.5 μm, $2 \cdot 10^{-3}$

Proton ignition is a newer concept avoiding the complexity of electron energy transport

- Same driver and fuel assembly options

- Novel collimated proton beam first seen at Nova PW

R Snavely et al
Phys Rev Letts
85,2945,(2000)



- Simpler proton energy transport by ballistic focusing from a concave surface

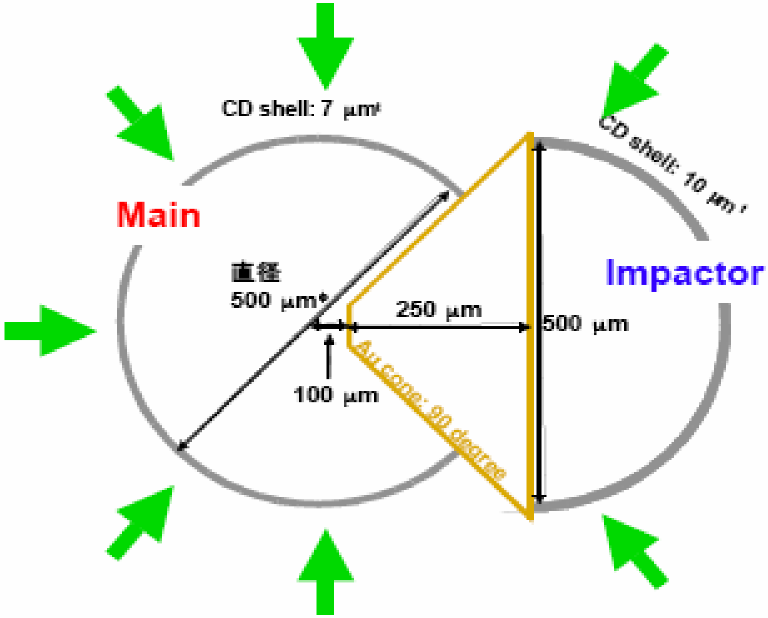
Proposed by
M. Roth *et.al.*
Phys Rev. Lett
86,436 (2000).

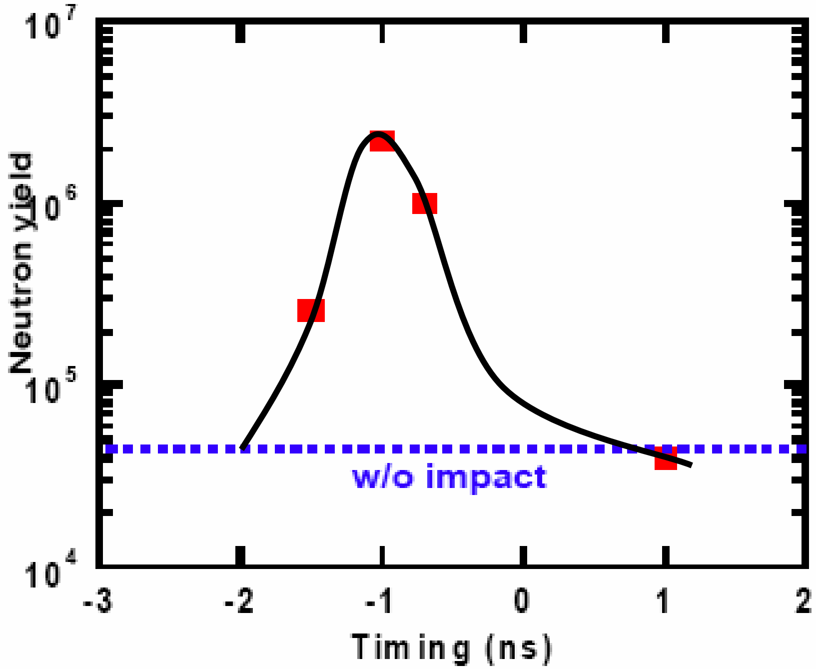
Experimental results

Neutron yield is enhanced by the impact of hemispherical CD.

ILE Osaka

Schematic of the impact heating experiment





Main: 2ω, E = 3 kJ
CD shell 7 µmt
Diameter = 500 µmφ
Impactor: 2ω, I < 200 TW/cm²
Hemispherical CD 10 µmt
Disameter = 500 µmφ

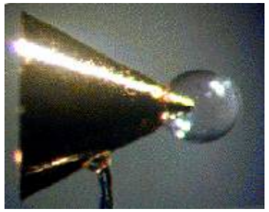
Neutron yield with impact is about a hundred times as large as that without impact.

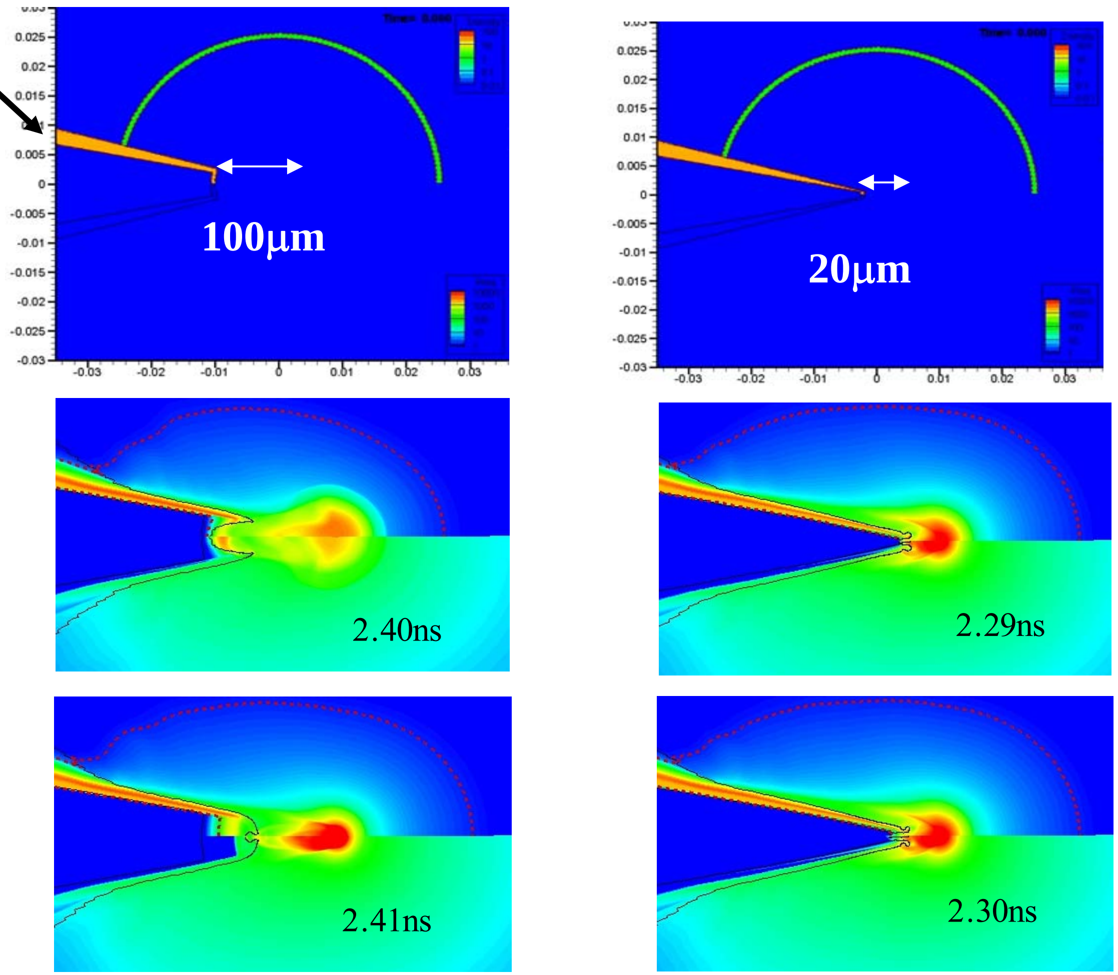
FIREX-I target design-I

Cone target position dependence of implosion and cone break

The cone top breaking time is insensitive to cone top position.

Gold cone



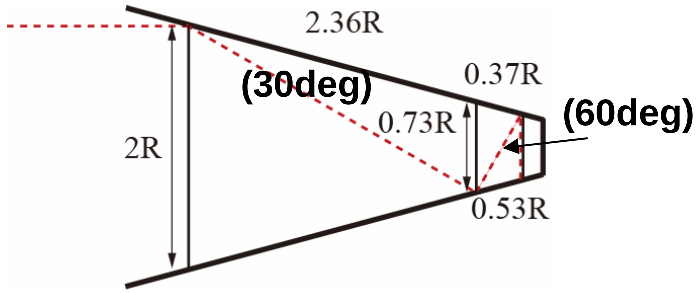


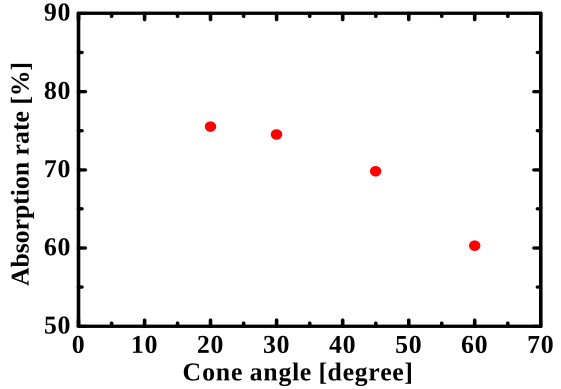
Density contour

Temperature contour

Two cone parameters, cone angle and tip/laser spot ratio, characterize the electrons generated from cone targets

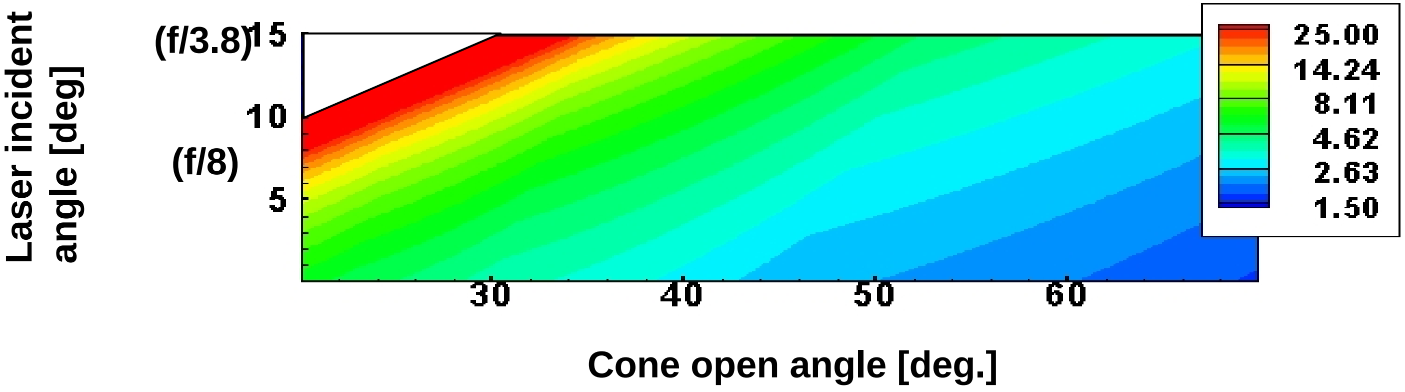
Cone angle changes laser propagation; smaller cone angle leads to higher absorption





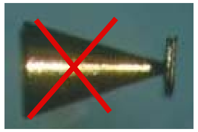
Cone tip/laser spot ratio together with cone angle change laser intensification at cone tip

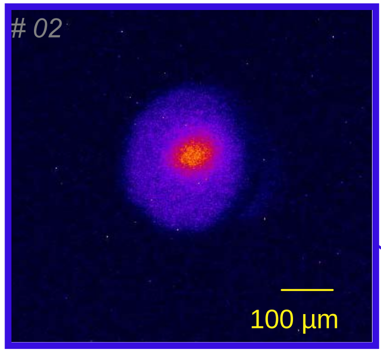
Maximum tip/spot size ratio determining intensification factor

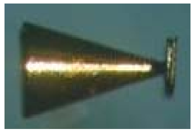


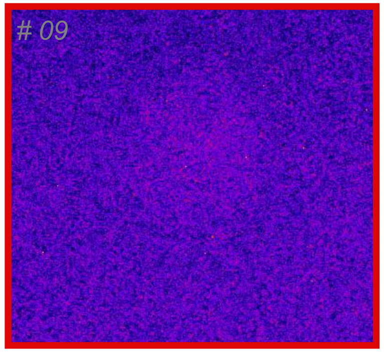
At ω, strong reduction of Kα signal in presence of cone implying drastic reduction of electron number and no target heating

Cu-Kα image

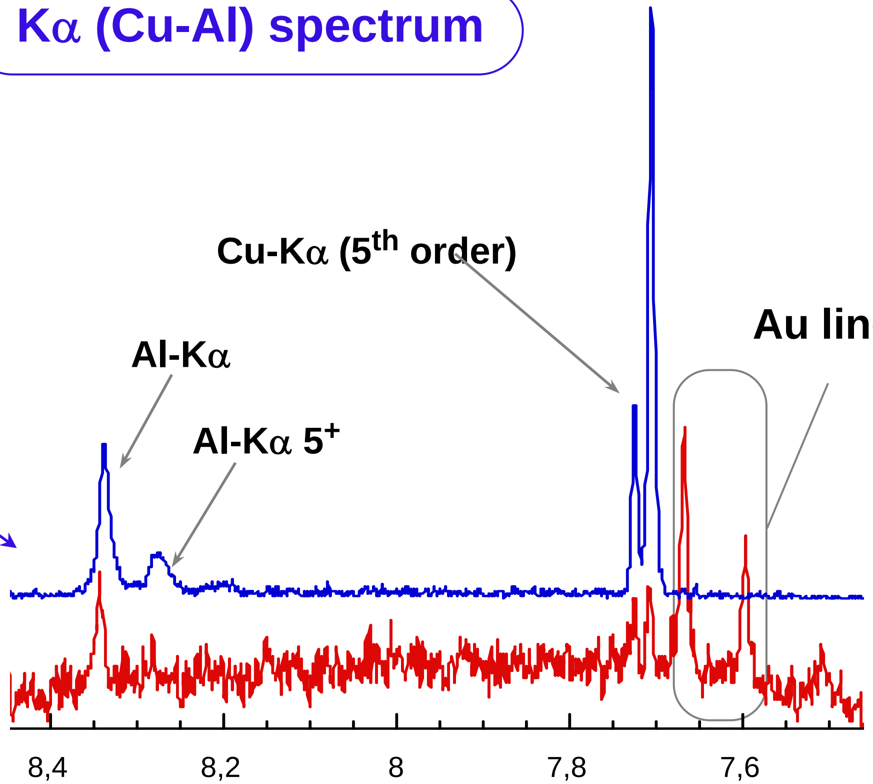






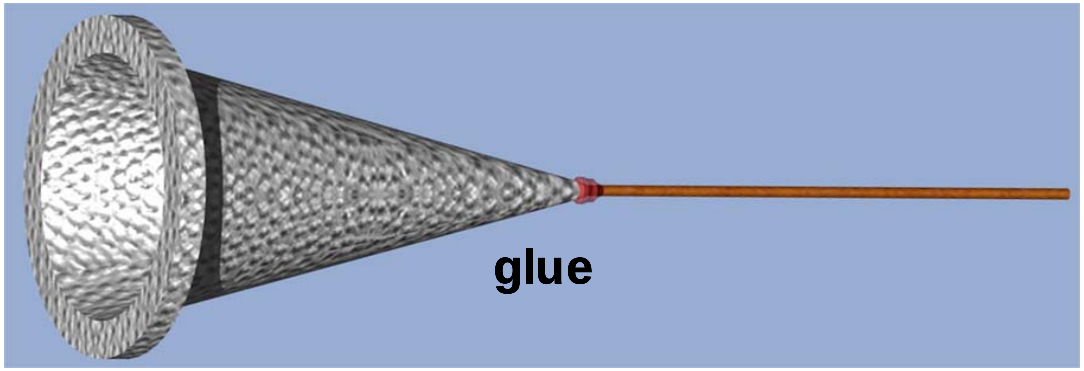


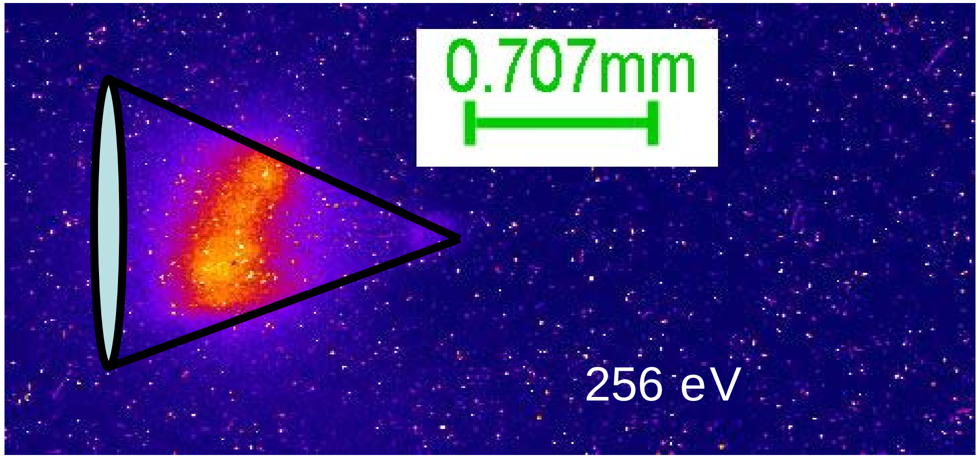
Kα (Cu-Al) spectrum



Ponderomotive and pre-pulse effects (double scale?) may be critical to compare results from different laser drivers

Laser Plasma Interaction (LPI) inside the cone is an interesting issue for the advanced Fast Ignition





- XUV (256 eV) images show emission from the large area inside the cone (laser spot size ~ 10 µm)
- Emission was also observed near the tip of the cone
- What is the role of the prepulse?

- **It is important to understand transport without a complexity of the cone**

F Beg at al

Time refraction

J. T. Mendonça GoLP and CFIF, Instituto Superior Técnico

A. Classical

1) - Temporal Snell's law:

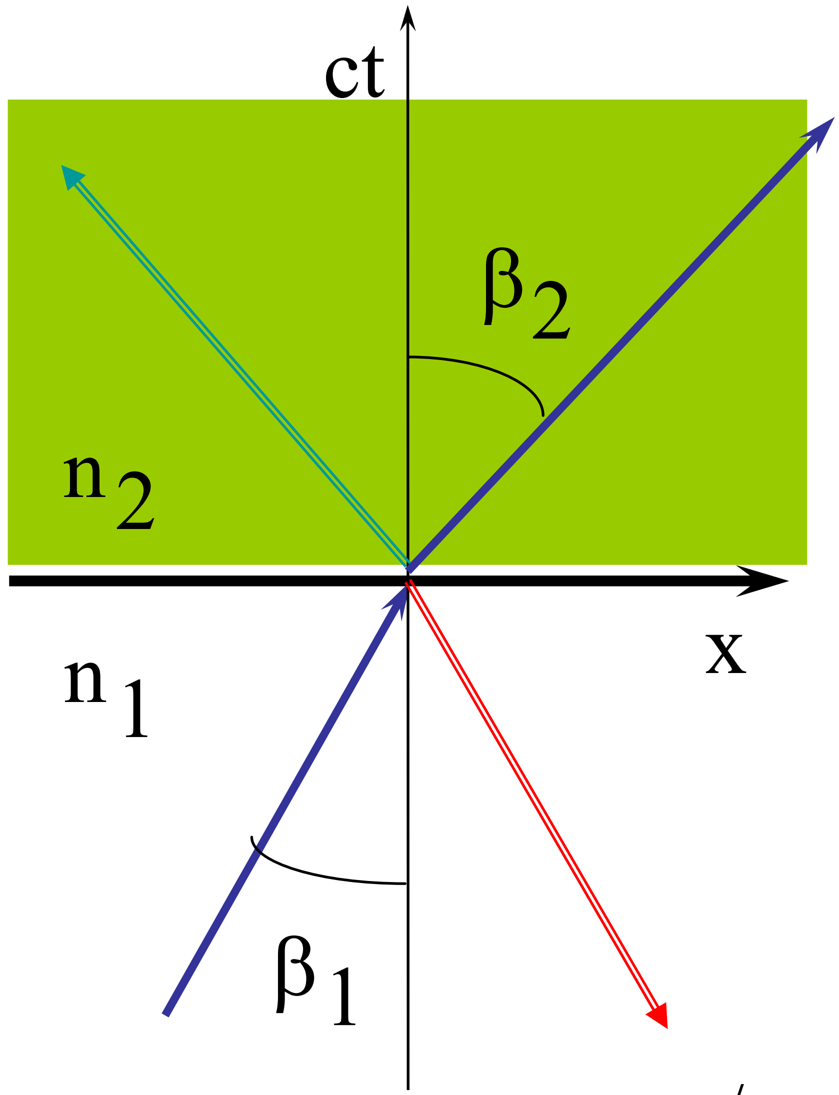
$$\omega_0 n_0 = \omega_1 n_1$$

Already observed (strong experimental evidence)

2) - Temporal Fresnel formulae

$$R = \frac{E_1'}{E_0} = \frac{\alpha}{2}(\alpha - 1), \qquad T = \frac{E_1}{E_0} = \frac{\alpha}{2}(\alpha + 1)$$

Some experimental evidence (no quantitative study)



$$\alpha = n_1 / n_2$$

Quantum vacuum

Photon pair creation (entangled states)
Not yet observed

Number of photons pairs

$$\langle N_k(t) \rangle = \sinh^2[r(t)]$$

Squeezing parameter

$$r(t) = \int_0^t \left[\omega(t')n^2(t')\right]^{-1} \left(\frac{dn}{dt'}\right)^2 dt'$$

1) - Vacuum effects in a medium

Possible (N >1), with high laser intensities

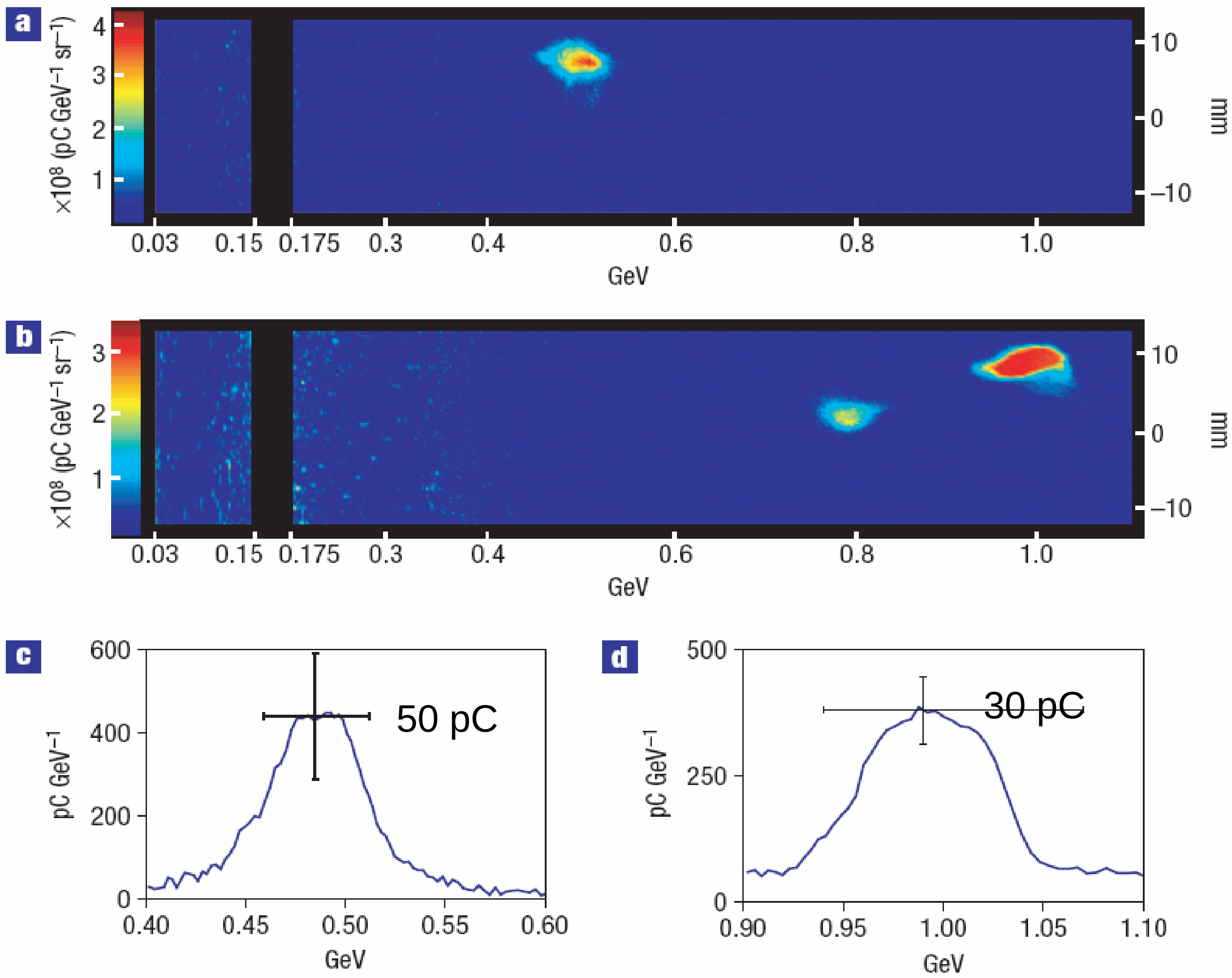
2) - Superluminal ionization fronts

Possible (N >1), with existing ultra-intense lasers

3) - Pure vacuum

Doubtful (N <<1), in the near future

GeV Laser Plasma electron beams



W. Leemans, … S.Hooker, et al., (Nature Physics 2006)

Acceleration to 1 GeV in 33 mm long pre-formed plasma channels

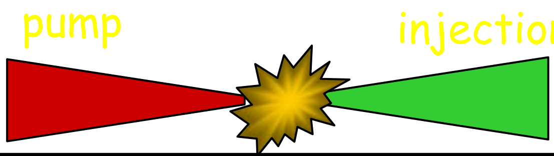
5% shot-to-shot fluctuations in mean energy @ 0.5 GeV

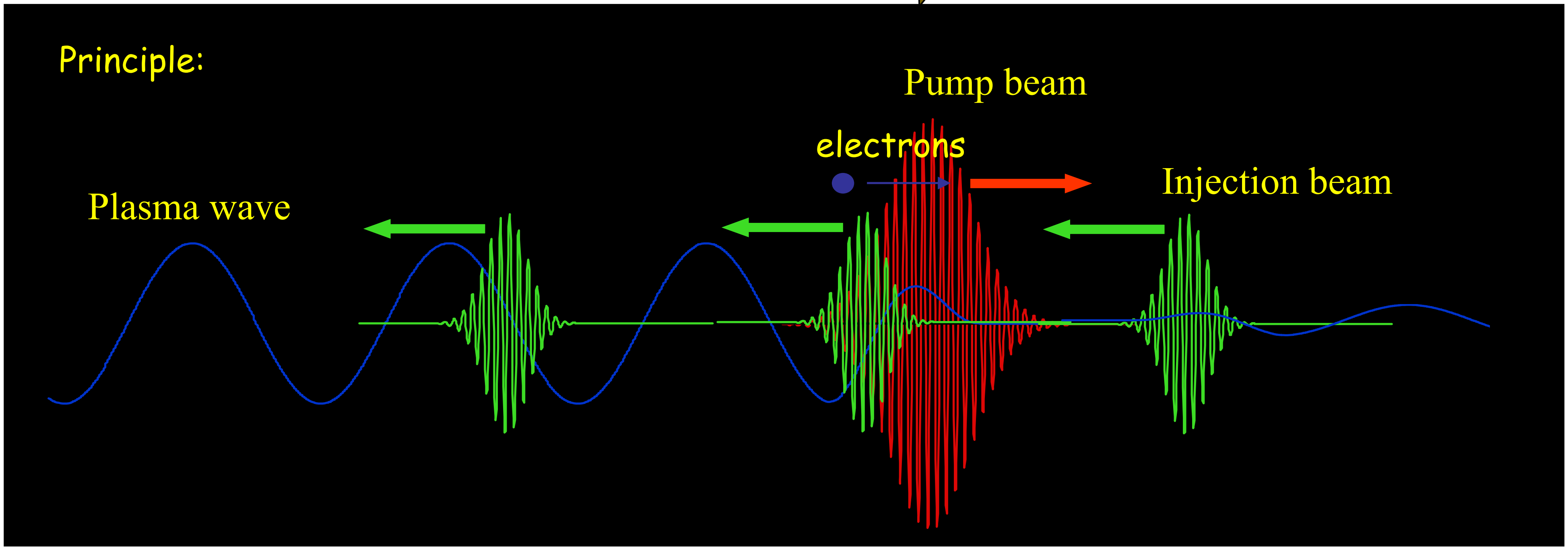
12TW (73fs) - 18TW (40fs)

E = (0.50 +/-0.02) GeV
ΔE = 5.6% r.m.s
$\Delta\theta$ = 2.0 mrad r.m.s.
Q = 50 pC
Laser ~ 1 J

Controlling the injection

Counter-propagating geometry:





Ponderomotive force of beatwave: $F_p \sim 2a_0a_1/\lambda_0$ (a_0 et a_1 can be "weak")

Boost electrons locally and injects them: y

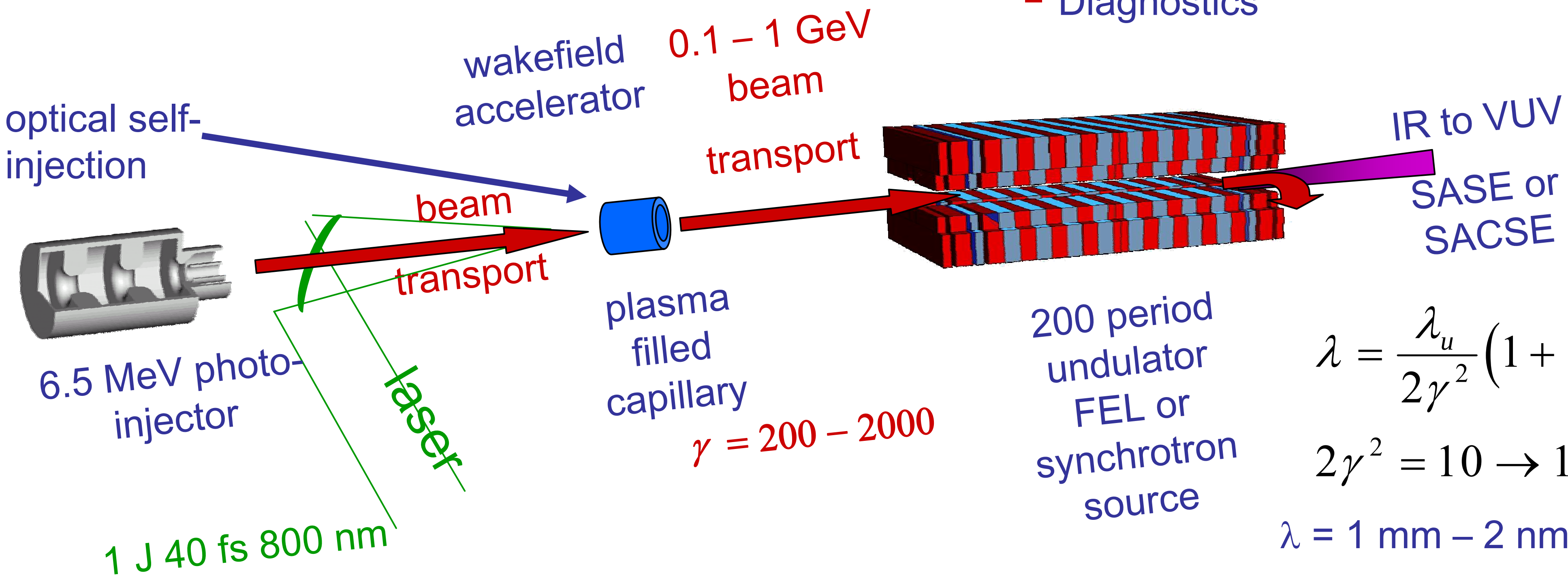
INJECTION IS LOCAL IN FIRST BUCKET y

E. Esarey et al, PRL 79, 2682 (1997), G. Fubiani et al. (PRE 2004)

Secondary sources ALPHA-X

Advanced Laser-Plasma High-energy Accelerators towards X-rays

- Injectors (conventional and all-optical)
- Laser-plasma wake-field acceleration
- Plasma capillaries
- Free-electron laser (FEL)
- Beam transport systems
- Diagnostics



$$\lambda = \frac{\lambda_u}{2\gamma^2}\left(1 + a_u^2\right)$$

$$2\gamma^2 = 10 \rightarrow 10^7$$

λ = 1 mm – 2 nm

UK consortium:

consortium

Synchrotron radiation peak brilliance

$I(k) \sim I_0(k)(N+N(N-1)f(k))$

N_u = 200

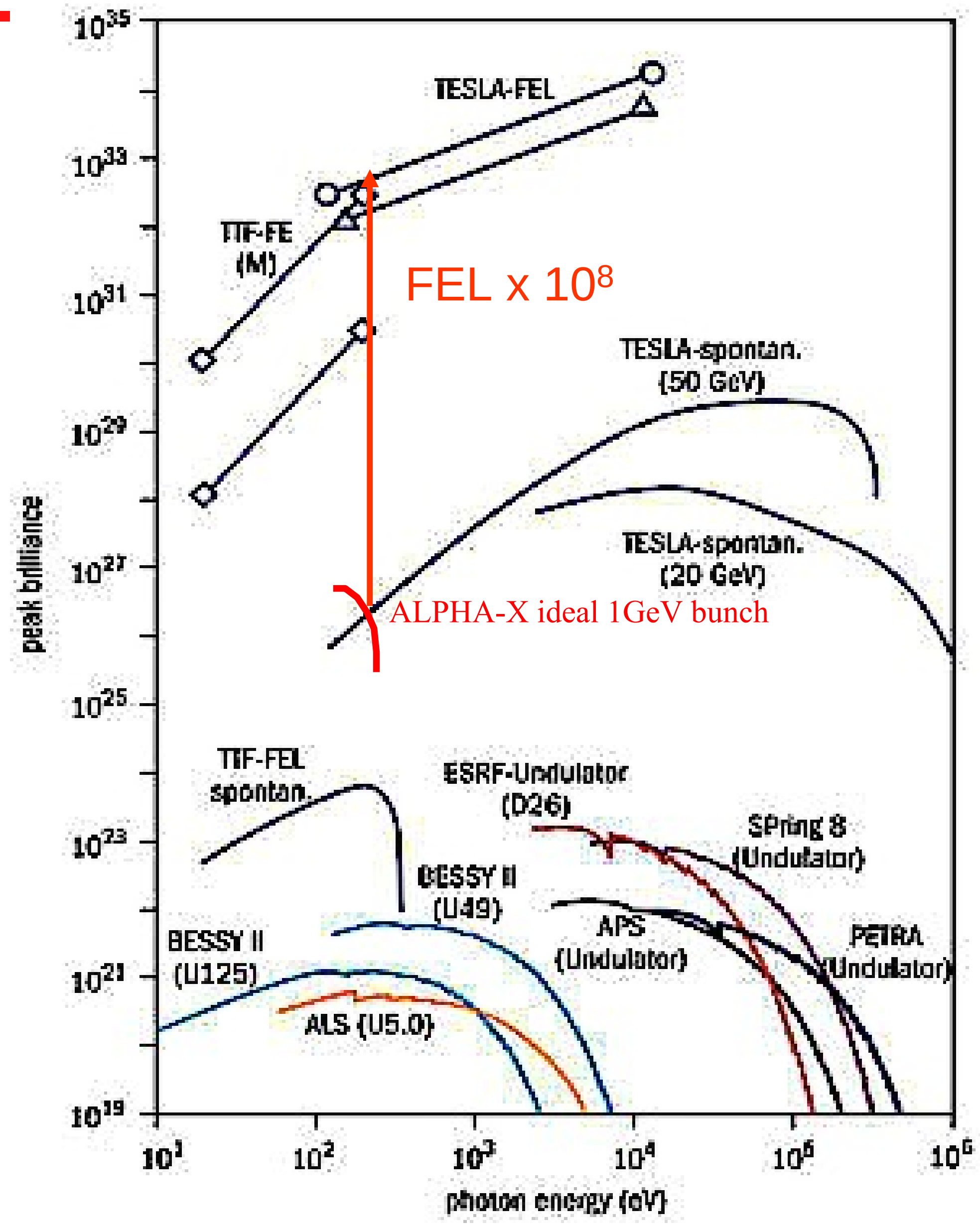
e_n = 1 p mm mrad

t_e = 10 fs

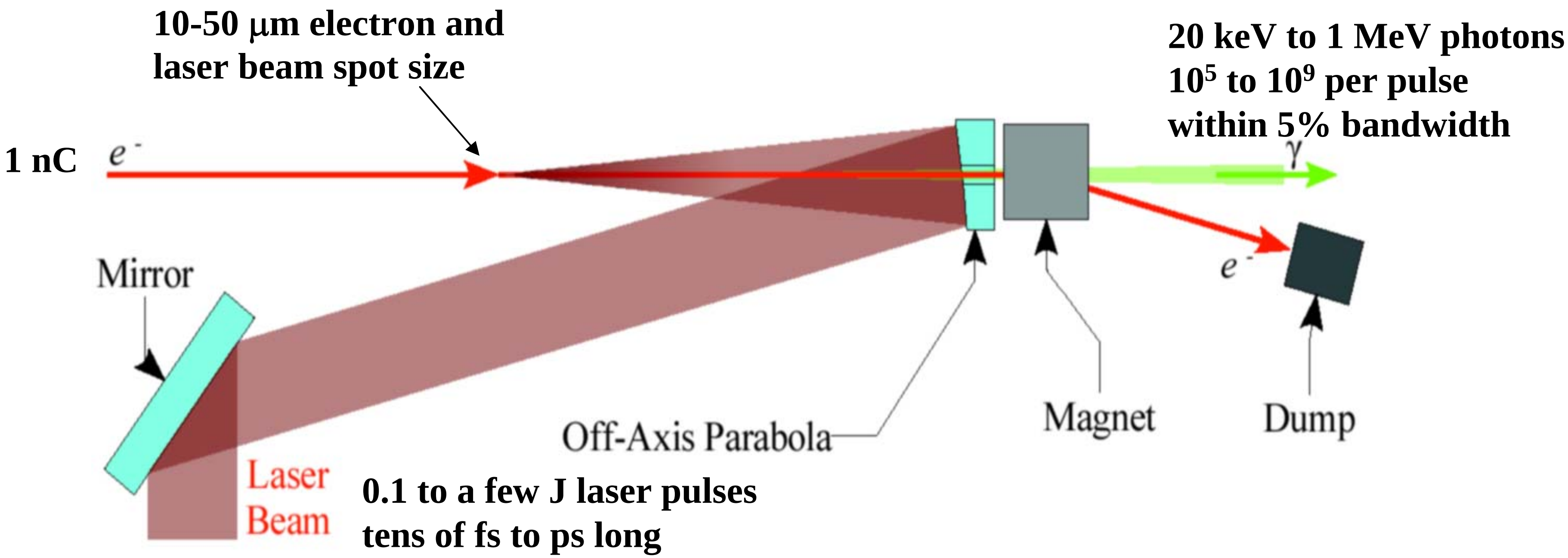
Q = 100 – 200 pC

I = 25 kA

FEL: Brilliance 5 – 7 orders of magnitude larger



Experimental set-up for the generation of tunable X-ray radiation via Thomson scattering of optical photons by relativistic electron bunches



FEL Amplification with kA e^- beams and ultra-stable ($\Delta I/I$, $\Delta\omega/\omega = 10^{-3}$) flat-top laser pulses. X-rays up to 10^{11} photons per pulse @ 6 keV, emitted in a coherent diffraction limited radiation beam, $\Delta\theta$=3 μrad
(vs. 10^9 ph/pulse in $\Delta\theta$=3 mrad of incoherent Thomson radiation)

Attosecond pulses

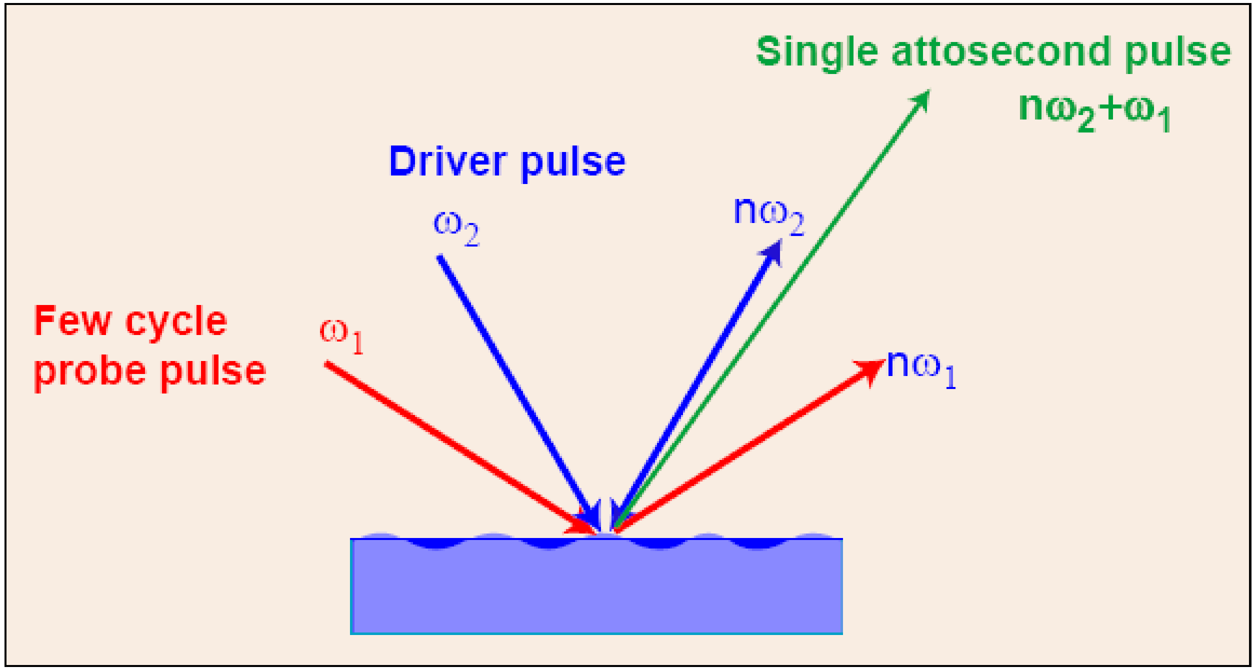
•Two beam mixing

• *ω_2-pulse drives plasma oscillations*
•*Few cycle ω_1-pulse produces a single attoscond pulse*

•Opens the way for new fields of study

Generation of high order Harmonics in steep plasma gradients at relativistic laser intensities

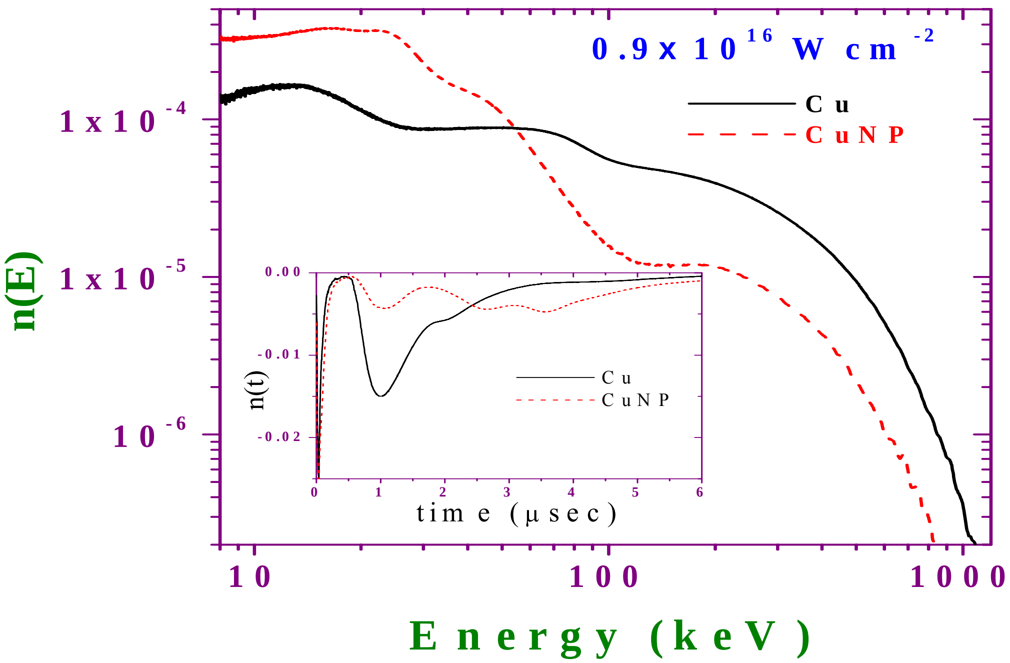
D. von der Linde and A. Tarasevitch
Institut für Experimentelle Physik
Universität Duisburg-Essen



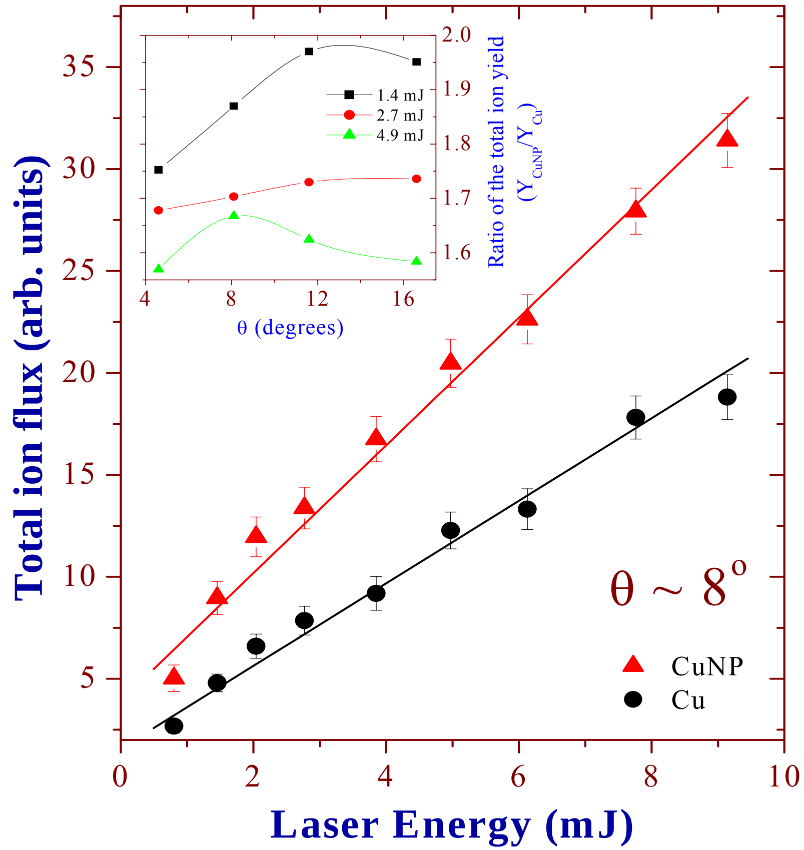
Does “Hotter” electrons lead to “faster” ions ?

FPPT 3

Not necessarily from (sub-λ) structured surfaces !!!
Local surface modulations lead to nonplanar plasma expansion
e.g: Cu nanoparticles of 15 nm size from 200 nm layer



Preferential enhancement of low energy ions

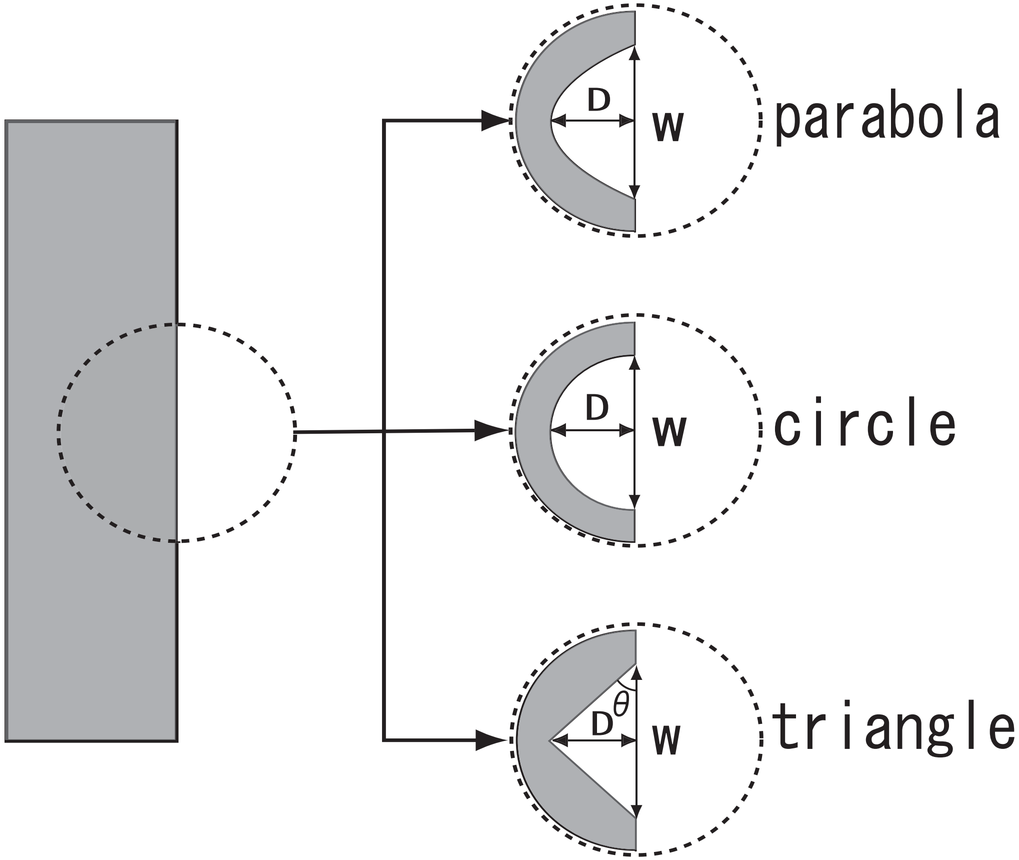


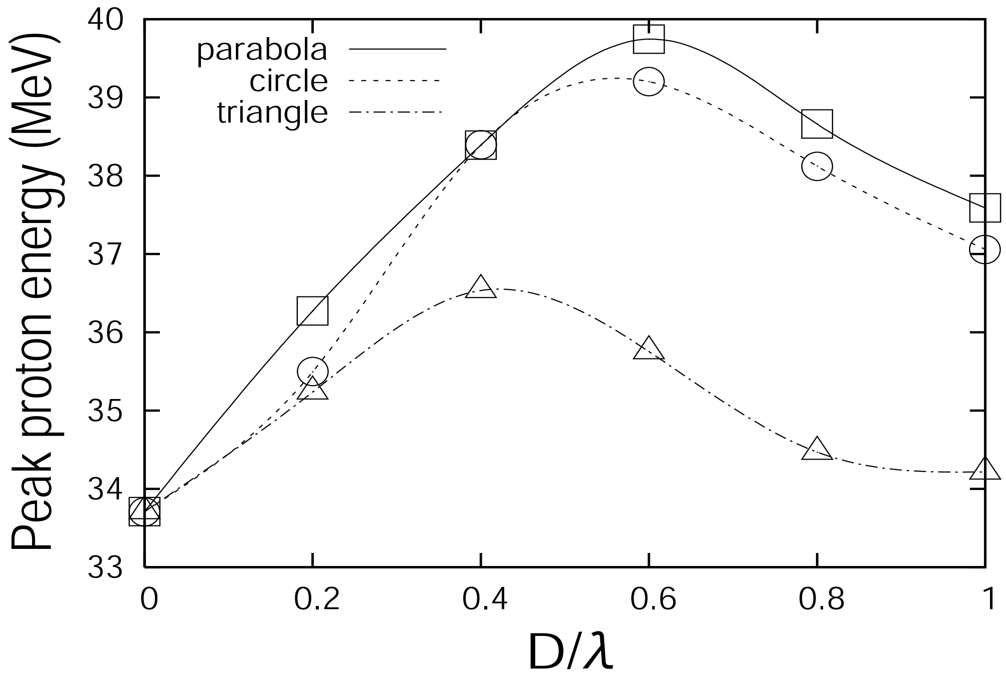
Preferential directionality to the ion beam
e.g: Cu nanoparticles of 15 nm size from 200 nm layer

Suman Bagchi, P. Prem Kiran, G. Ravindra Kumar
Tata Institute of Fundamental Research, Mumbai, India

Appli. Phys. Lett. (2007)

The geometry of the target containing the concave cavity



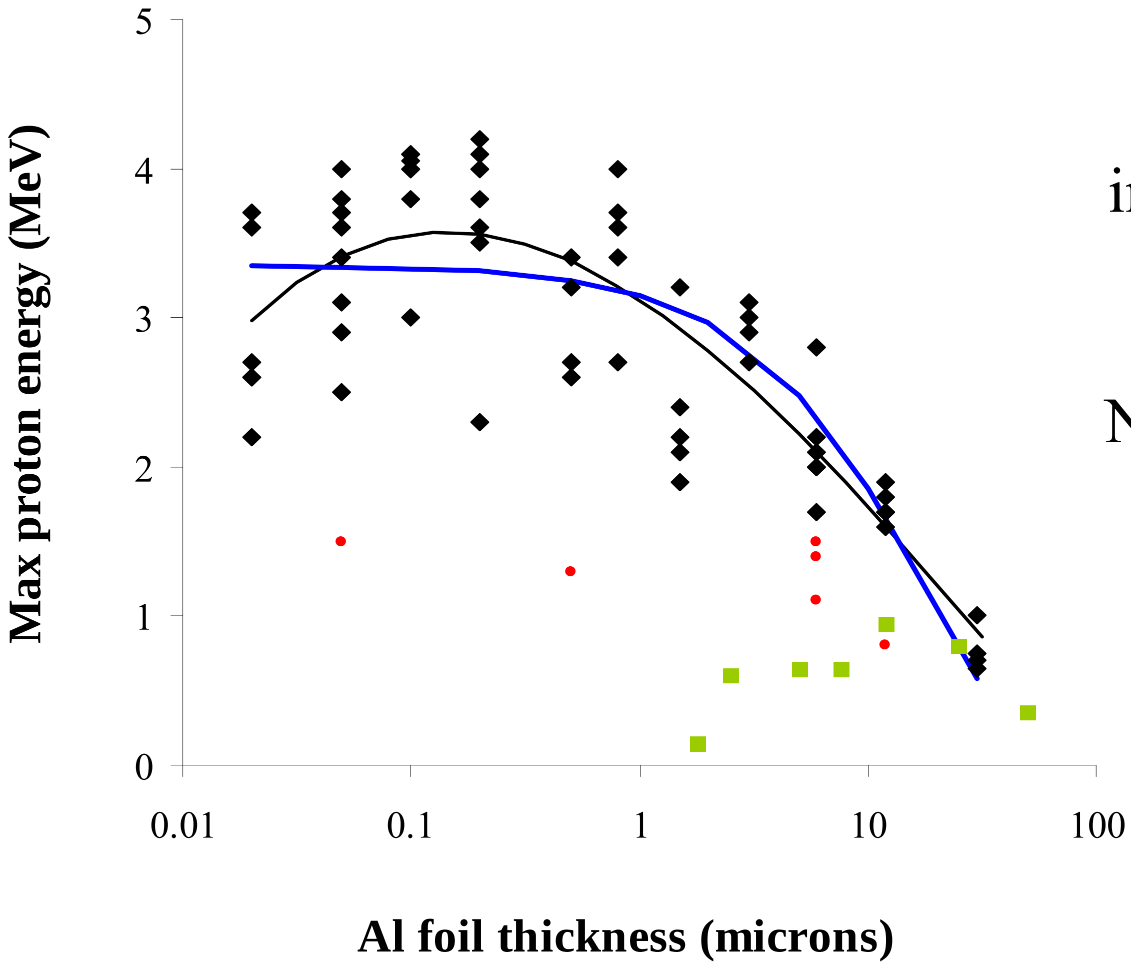


Peak proton energy vs depth of the concave shape (D/ λ) from the triangular, circular and parabolic concave targets at ωt=800.

Fast proton bunch generation in the interaction of ultraintense laser pulses with high-density plasmas

T.Okada *et al.*, Phys. Rev. E **74**, 026401 (2006)

Ion acceleration High contrast interactions



10^{10} contrast using plasma mirror enables interaction with ultra thin targets achieving higher efficiency

New ideas to control ion spectral energy distribution

New laser techniques give inherent contrast of 10^{10}

Studies using secondary ion driven interactions currently underway

D Neely et al, Appl. Phys. Lett **89**, 021502 (2006)

High efficiency ion acceleration RT instability

•At 10^{23} Wcm^{-2} We enter a regime of very high efficiency in a plasma foil

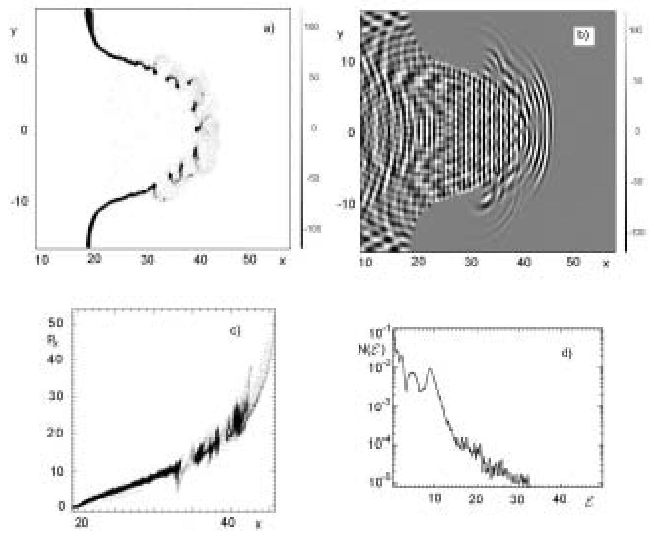
•Theoretical efficiency approaches 1

•Described by co-moving relativistic mirror model

•Regime is Raleigh Taylor unstable!!!

•This does not spoil the acceleration – changes spectrum

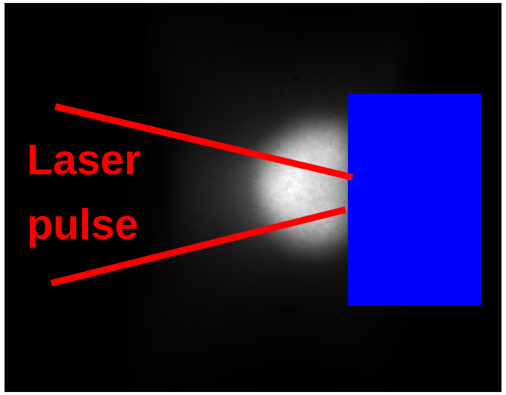
•In Al 1 GeV per nucleon



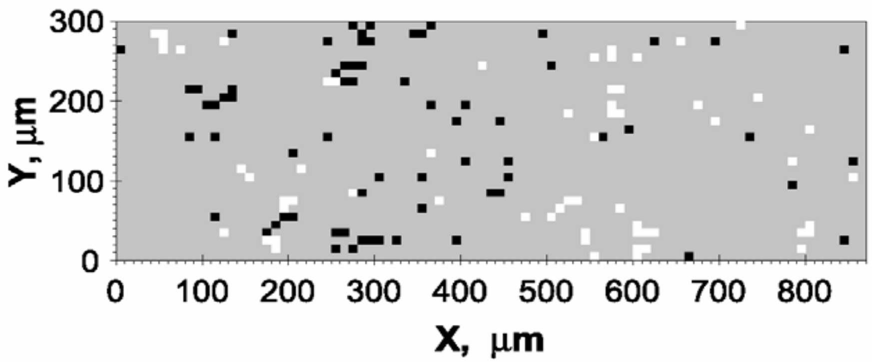
S V Bulanov F Pegorar

Laser-Induced Breakdown Spectroscopy for Microanalysis

R. Fedosejevs et al. (University of Alberta)

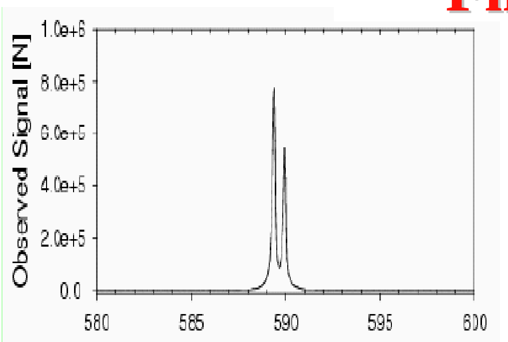


μLIBS Development and Applications

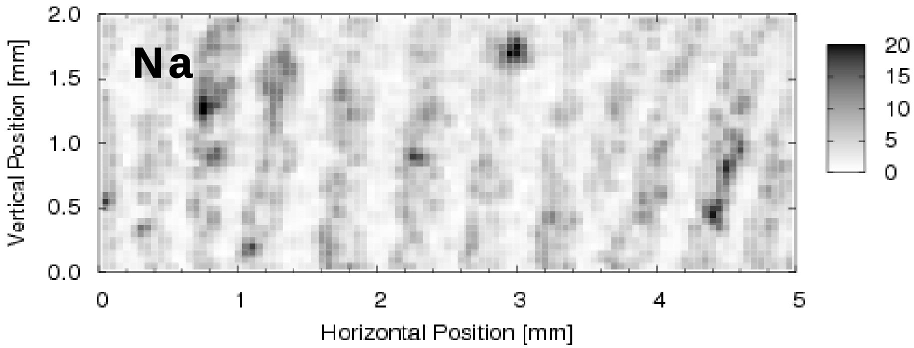


2D microanalysis of precipitate distribution in Al 2024

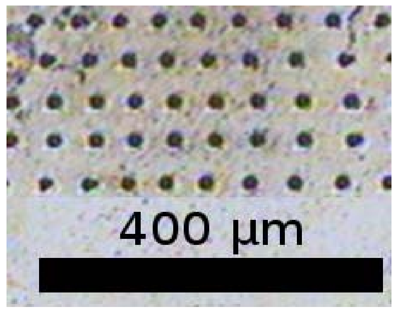
~100 μJ pulse energy 10μm resolution



Finger Print scan (5 μJ UV fs pulses)

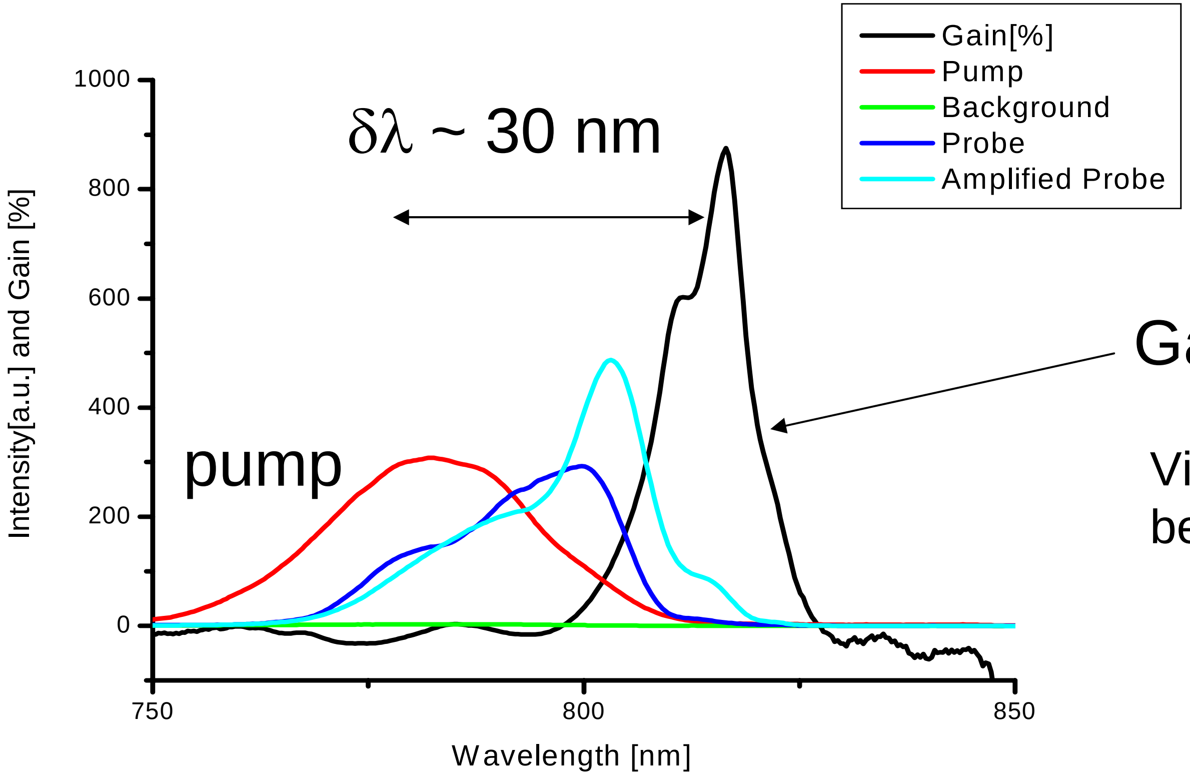


Sub 10 μm spots



Raman amplification in plasma

High gain – high efficiency high power capability



Vieux, .. Jaroszynski et al., to be published 2007

E_{pump} – 250 mJ, E_{probe} – 6 mJ

Peak efficiency = 5%

Physics and medical applications with laser plasma accelerators

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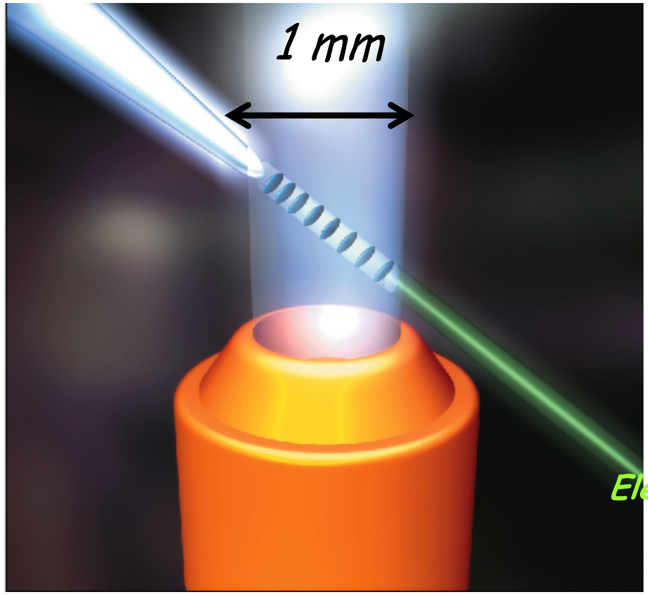
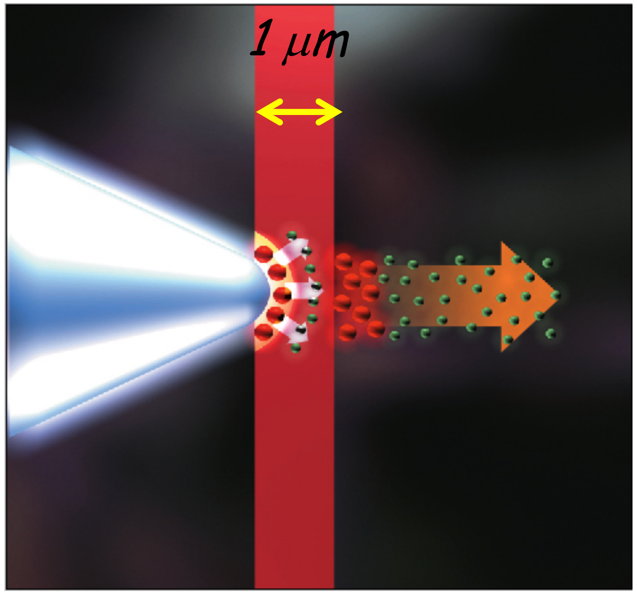
Victor Malka

LOA, ENSTA – CNRS - École Polytechnique,
91761 Palaiseau cedex,   France





Proton beam

Conclusions

- **Many exciting new developments**
  - **Astrophysics, EOS, Jets. Instabilities, sources, nuclear, attosecond physics**
- **FI**
  - **Cone coupling studies underway, pre-plasma effects critical**
  - **New facilities FIREX, EP, HIPER (proposal).**
- **Ultra-high intensity interactions**
  - **QED, e-acc, ion acc, Applications, High rep rate TT sources**
- **Interaction physics**
  - **Simulations, New amplifer- Raman**
- **International community is growing**