LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Munich-Center for Advanced Photonics

Novel particle and radiation sources enabled by nanotechnology and nanomaterials

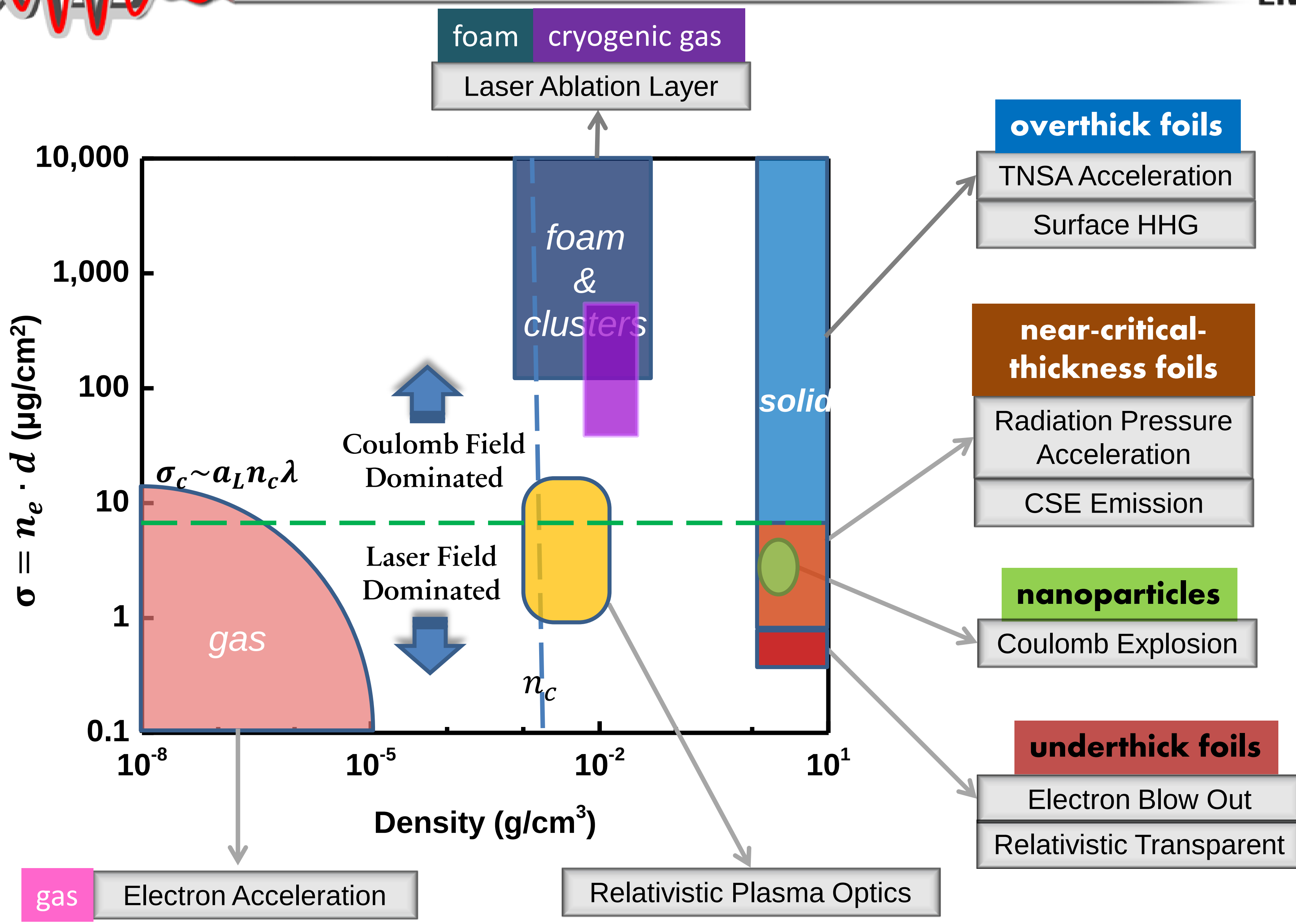
Wenjun Ma

Faculty of Physics, LMU

Cluster of Excellence "Munich-Centre for Advanced Photonics" (MAP)

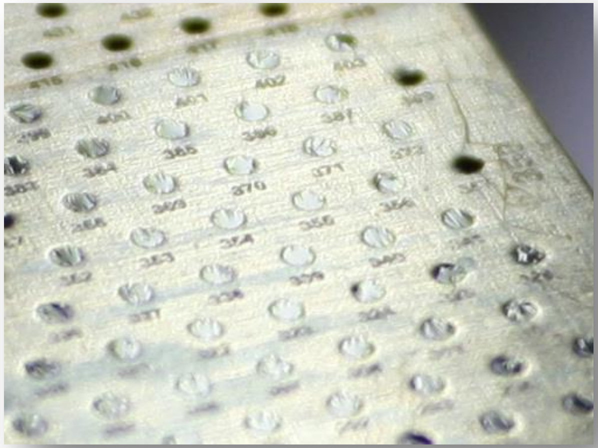
Our Group in Garching

Targets for Ultra-Intense Laser Pulses

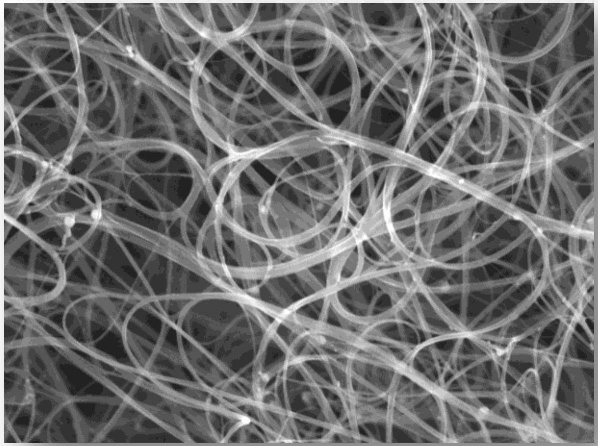


Nano-targetry at LMU

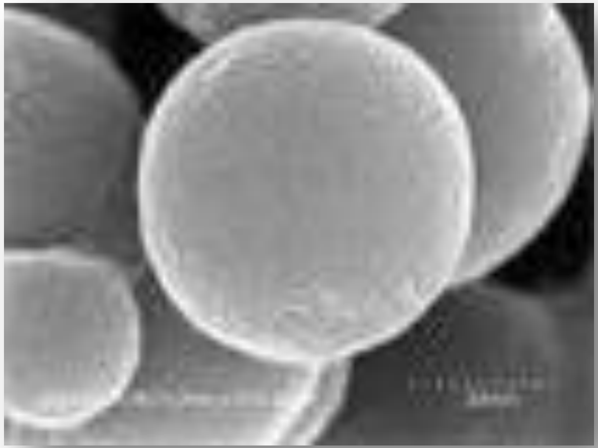
DLC Nanofoils



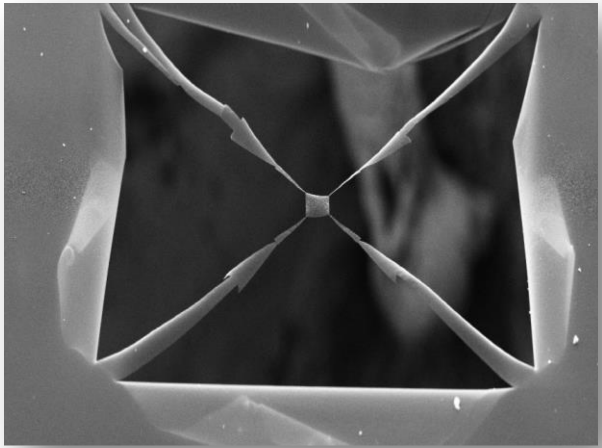
Carbon Nanotubes Foams



Elevating Nanospheres



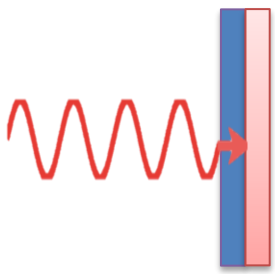
Structured Nanotargets

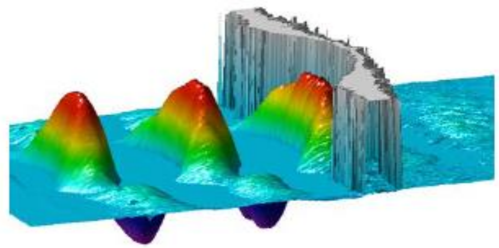


Ion Acceleration with Nanofoils

$\sigma \sim \sigma_c$

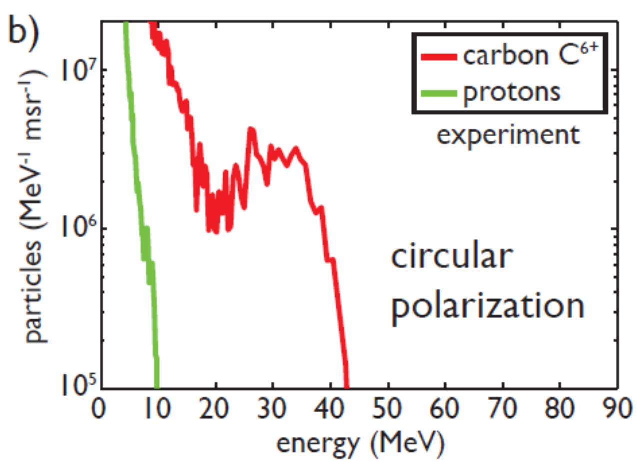
Radiation Pressure Acceleration (RPA)





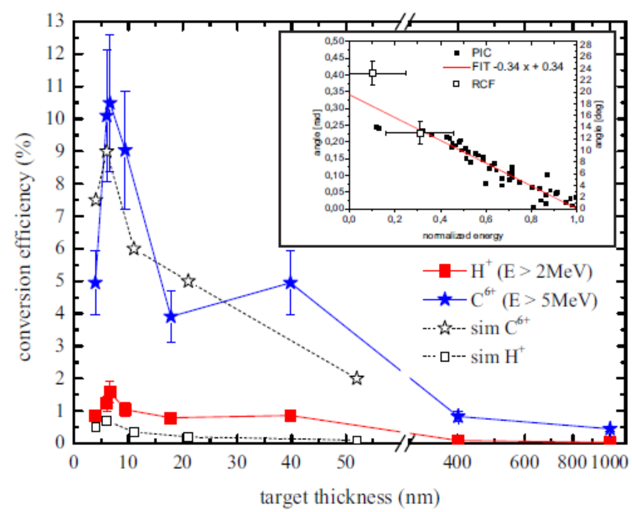
- ✓ high conversion efficiency (>10%)
- ✓ quasi monoenergetic peak

RPA in light sail regime



A. Henig et al. Phys. Rev. Lett. **103**, 245009 (2009).

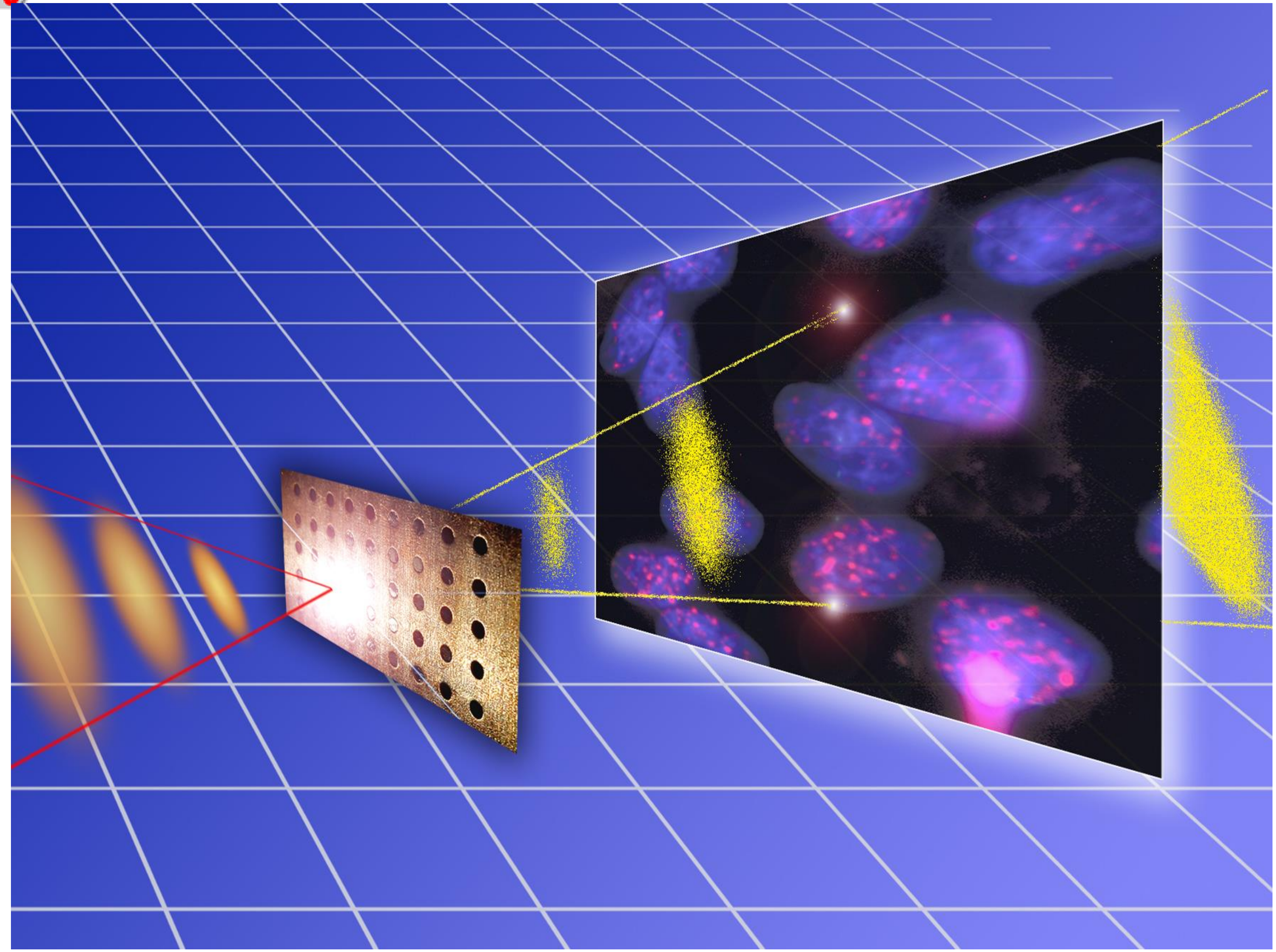
High efficiency



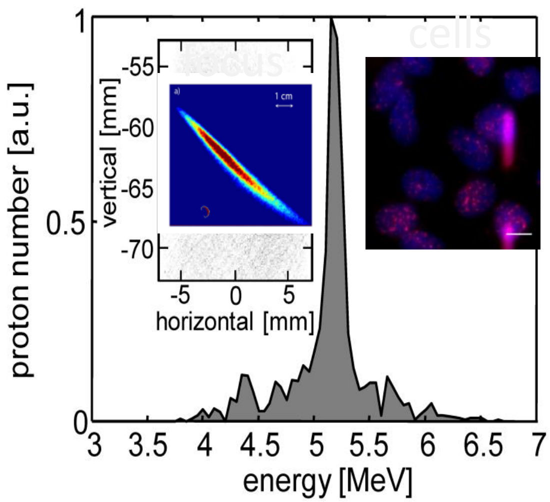
Steinke, S., A. Henig, et al. Laser and Particle Beams **28,** (2010).

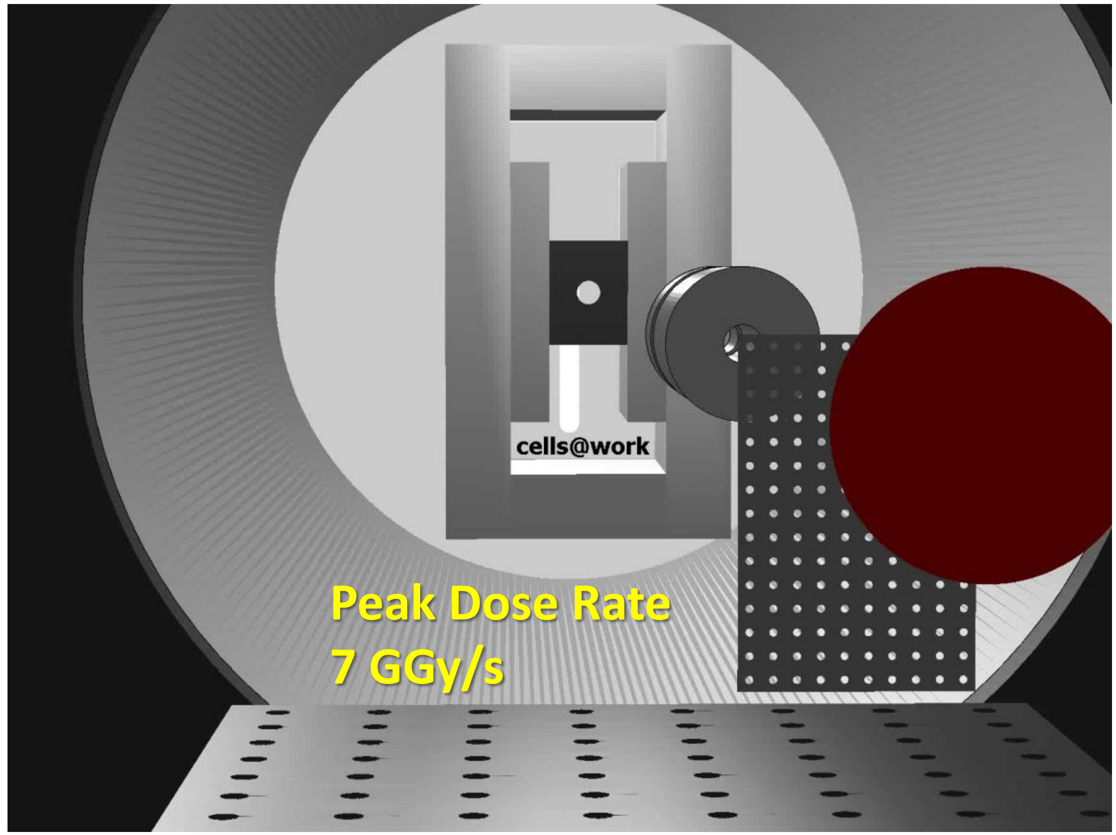
(in collaboration with MBI)

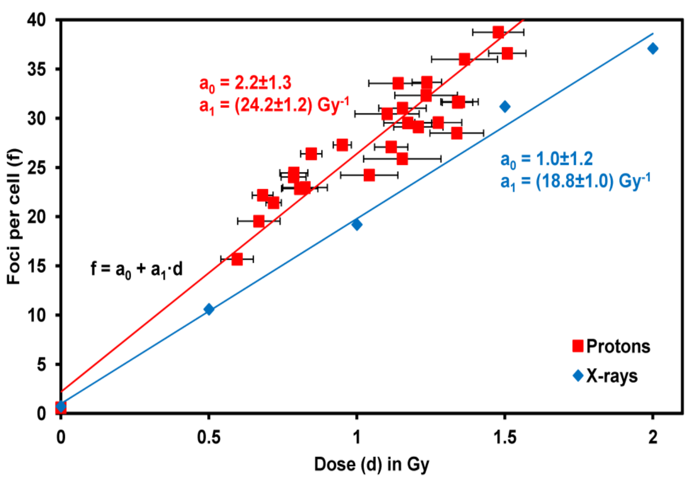
Biomedical Applications



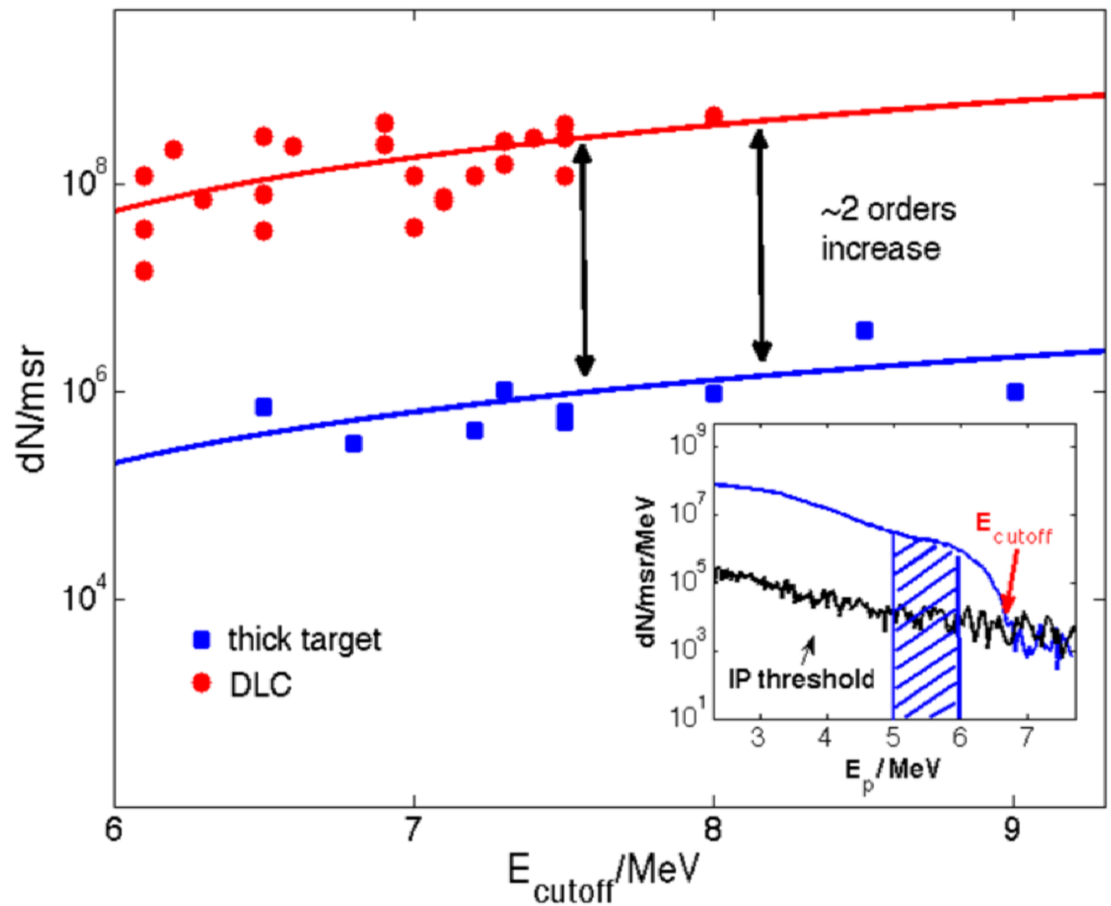
"A laser-driven nanosecond proton source for radiobiological studies."J. Bin *et al.*, Appl. Phys. Lett. 101, 243701 (2012) (Cover Letter)





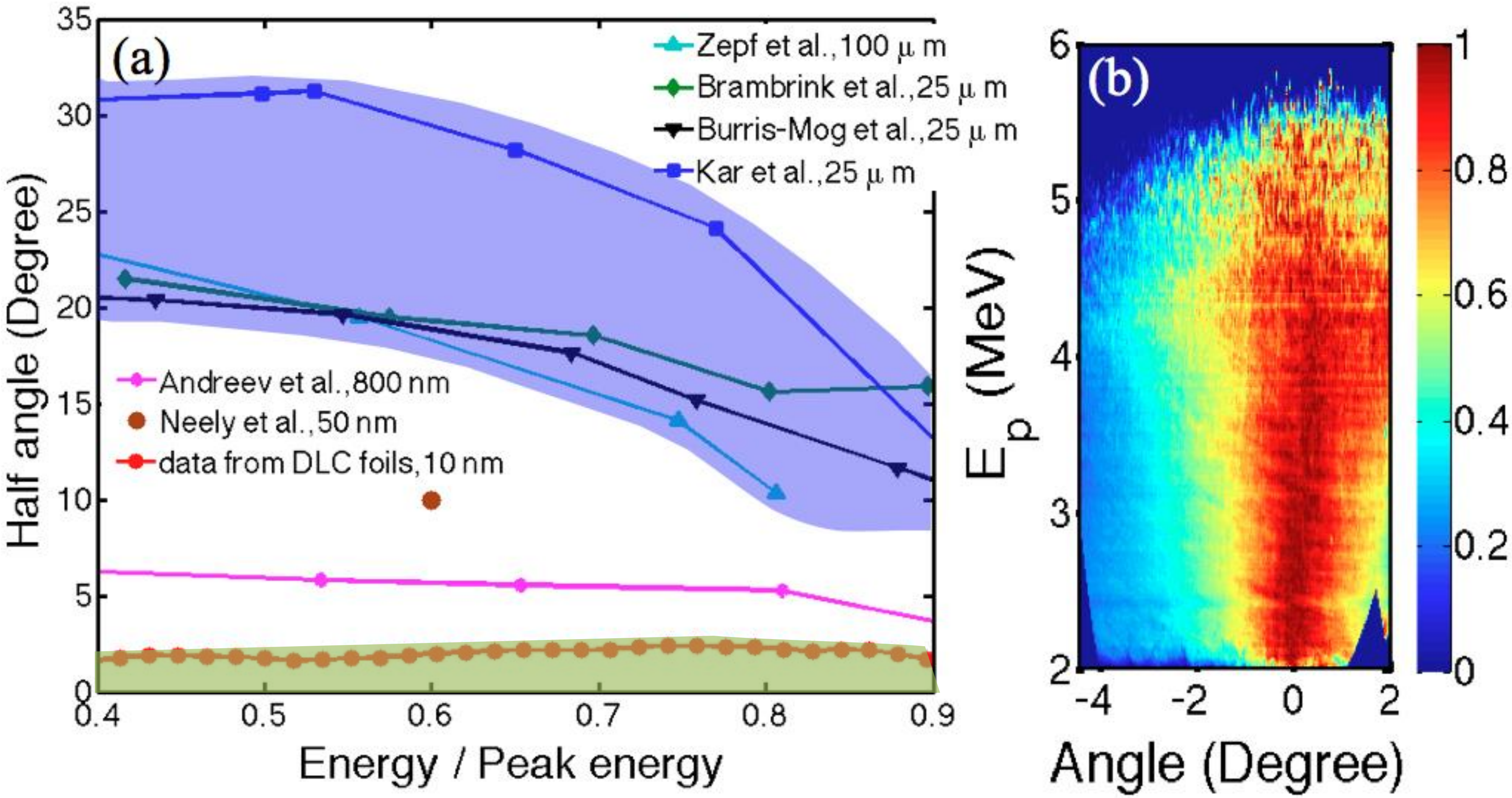


- radiate **2-7 Gy** ("lethal") dose in **one** single ns pulse
- dose response curve from a single shot
- low laser energy (400 mJ, 10 Hz operable)
- low background radiation
    - thick foils: few microSv / shot
    - DLC: 1-2 microSv / 50 shot



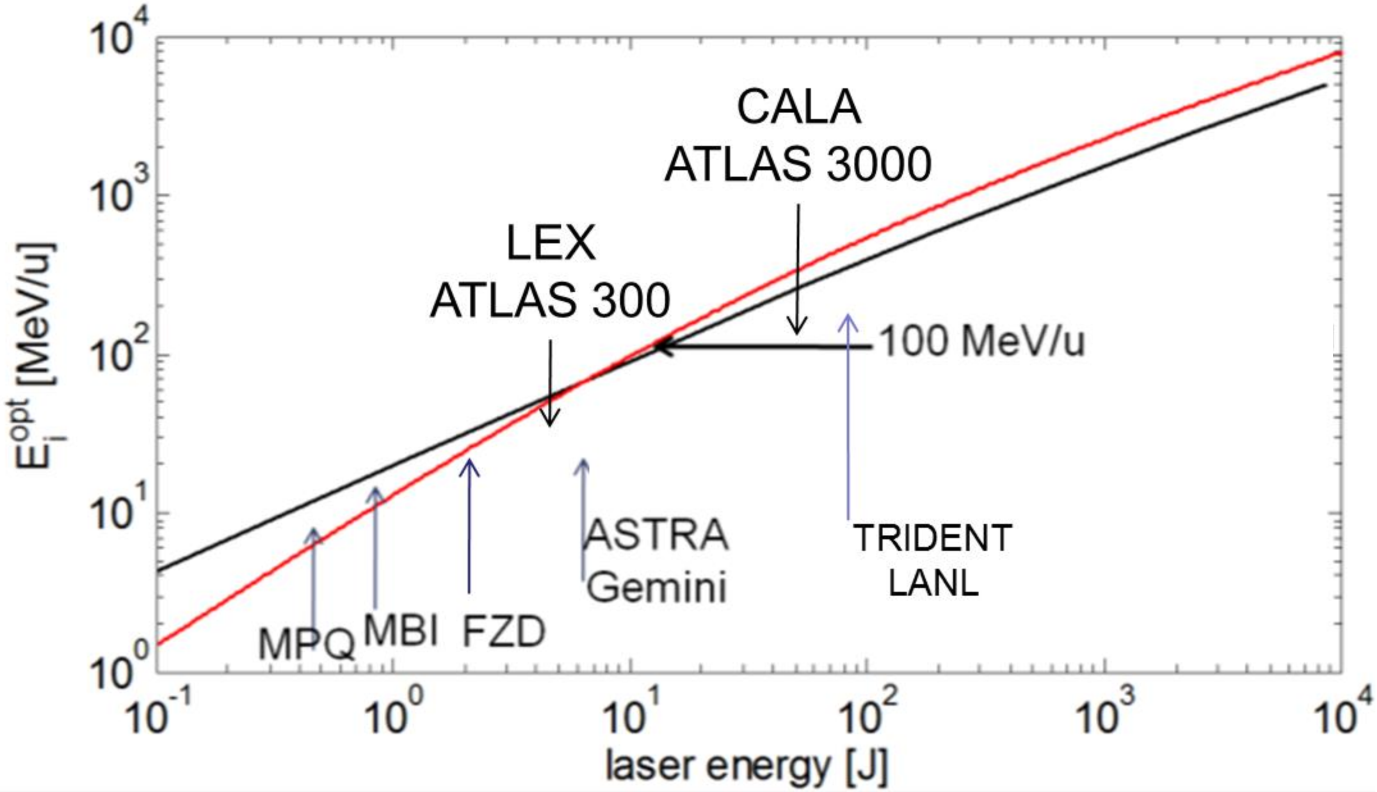
2 order of magnitude more flux for protons

Small Divergence of Ion Beams from Nanofoils



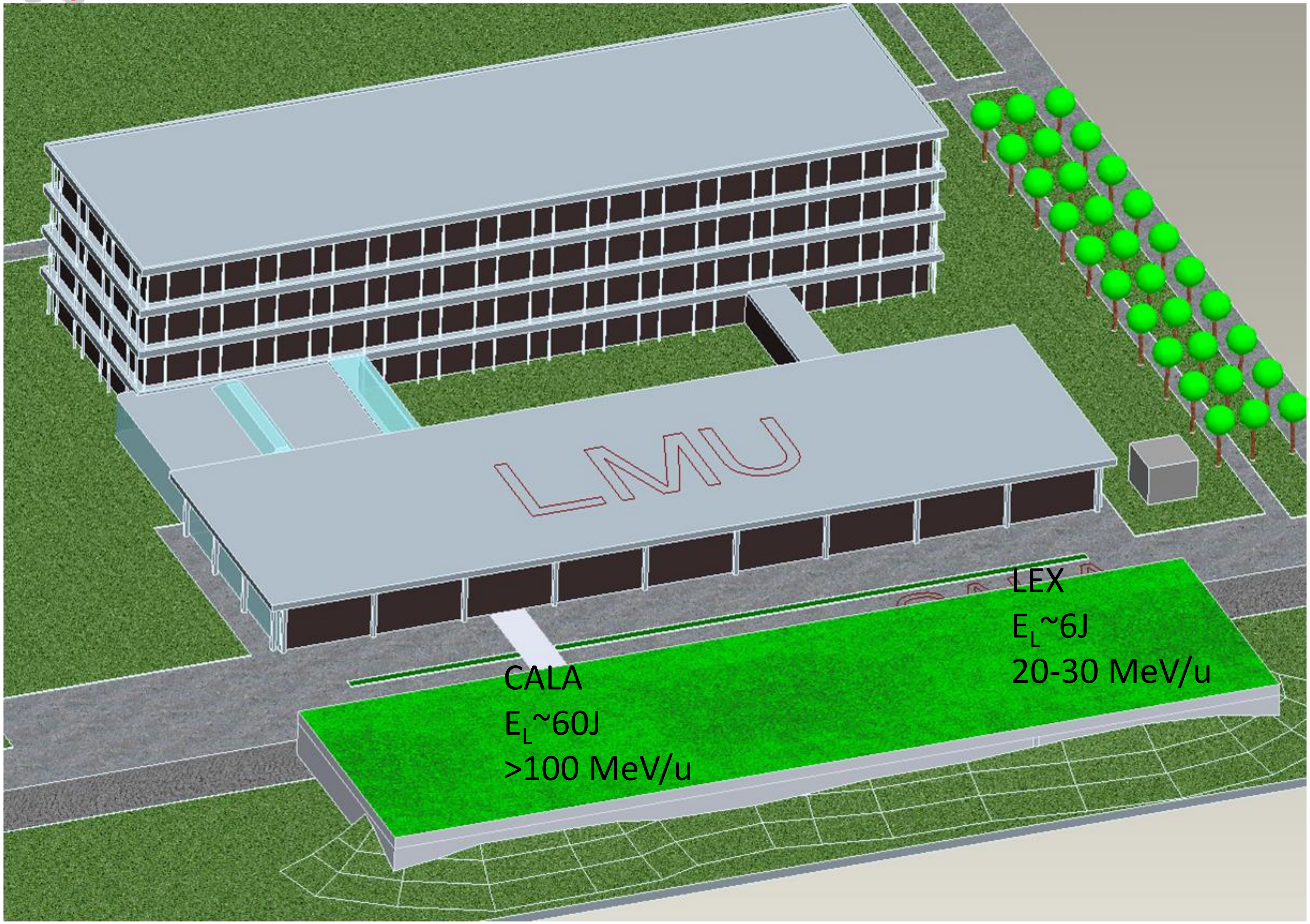
On the small divergence of laser-driven ion beams from nanometer thick foils. J.Bin, W.Ma et.al. Phys. Plasmas **20**, 073113 (2013)

Projection



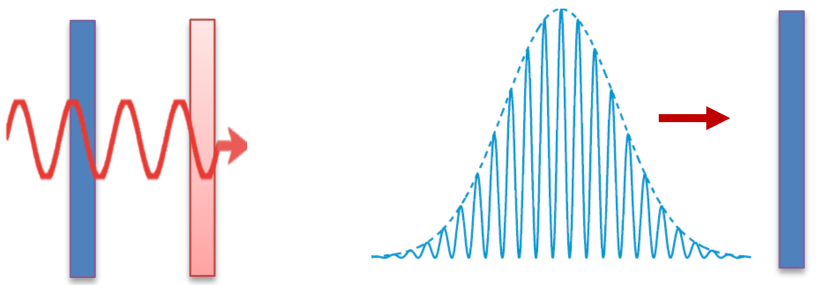
10^4
10^3
10^2
10^1
10^0
E_i^{opt} [MeV/u]
CALA
ATLAS 3000
LEX
ATLAS 300
100 MeV/u
ASTRA
Gemini
TRIDENT
LANL
MPQ
MBI
FZD
10^{-1}
10^0
10^1
10^2
10^3
10^4
laser energy [J]

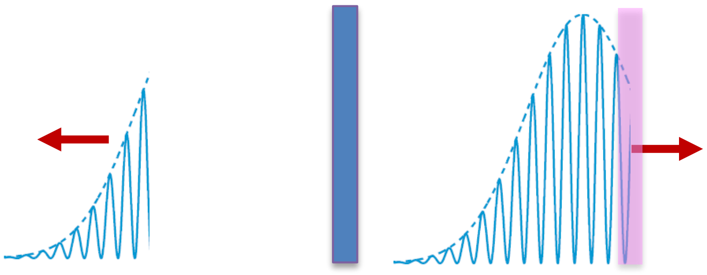
LEX and CALA at Garching



Underthick Targets

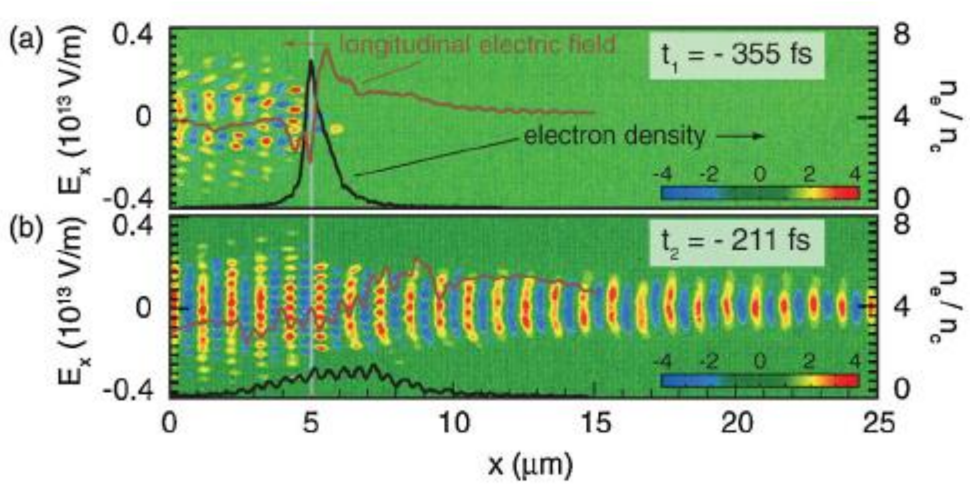
$\sigma < \sigma_c$

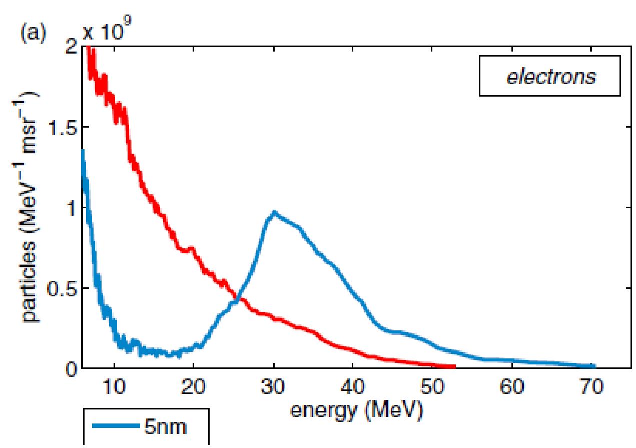




Relativistic transparency

Dense Electron Bunch Generation



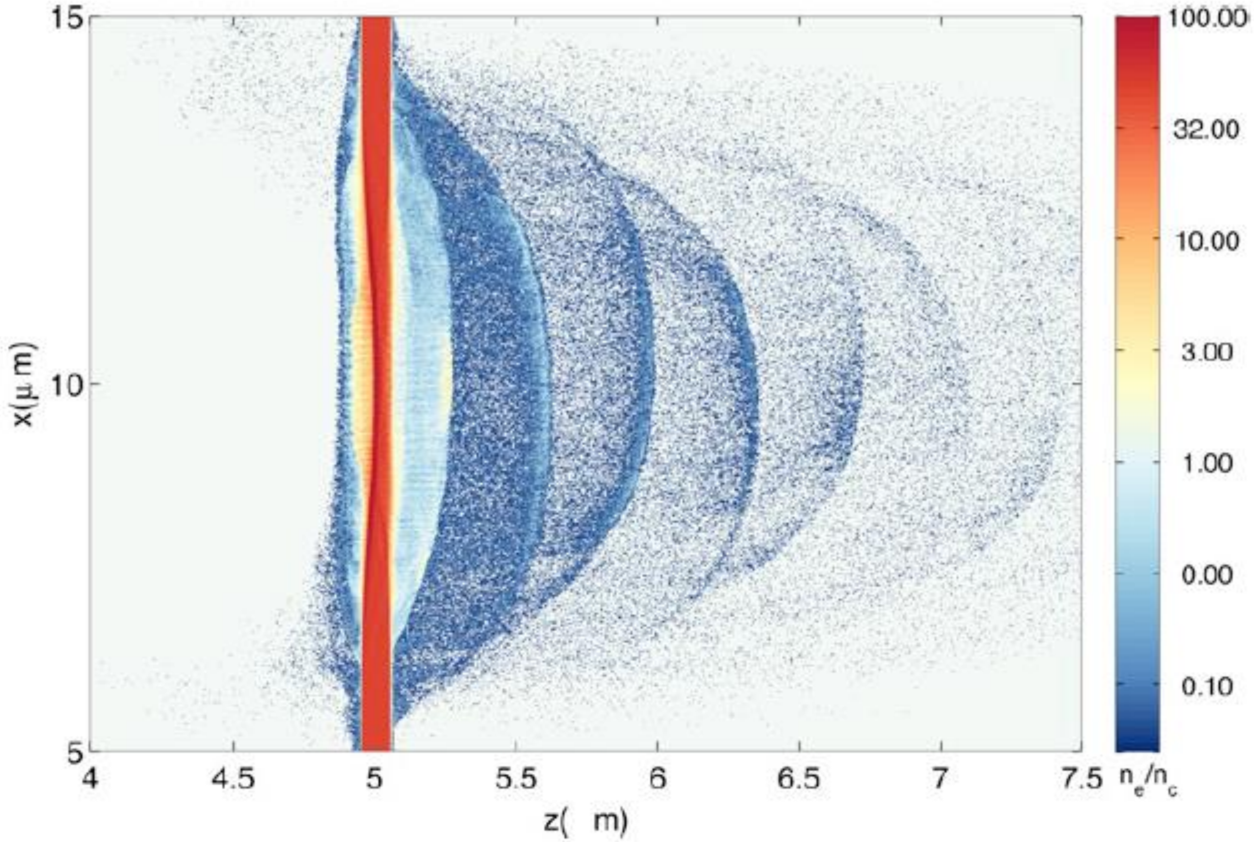


"Enhanced Laser-Driven Ion Acceleration in the Relativistic Transparency Regime." Physical Review Letters **103**(4)

Kiefer, D., A. Henig, et al. (2009). " European Physical Journal D **55**(2): 427-432.

(in collaboration with LANL)

Relativistic Flying Mirrors

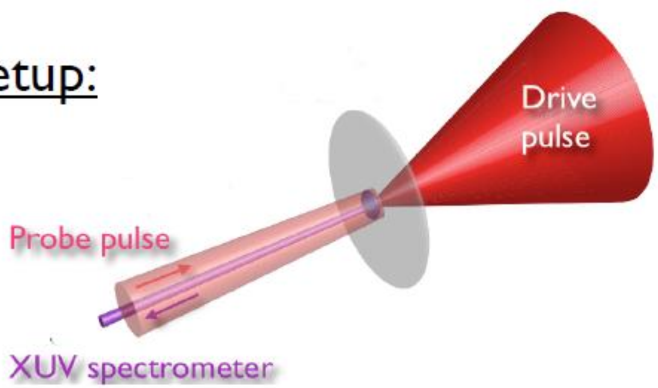


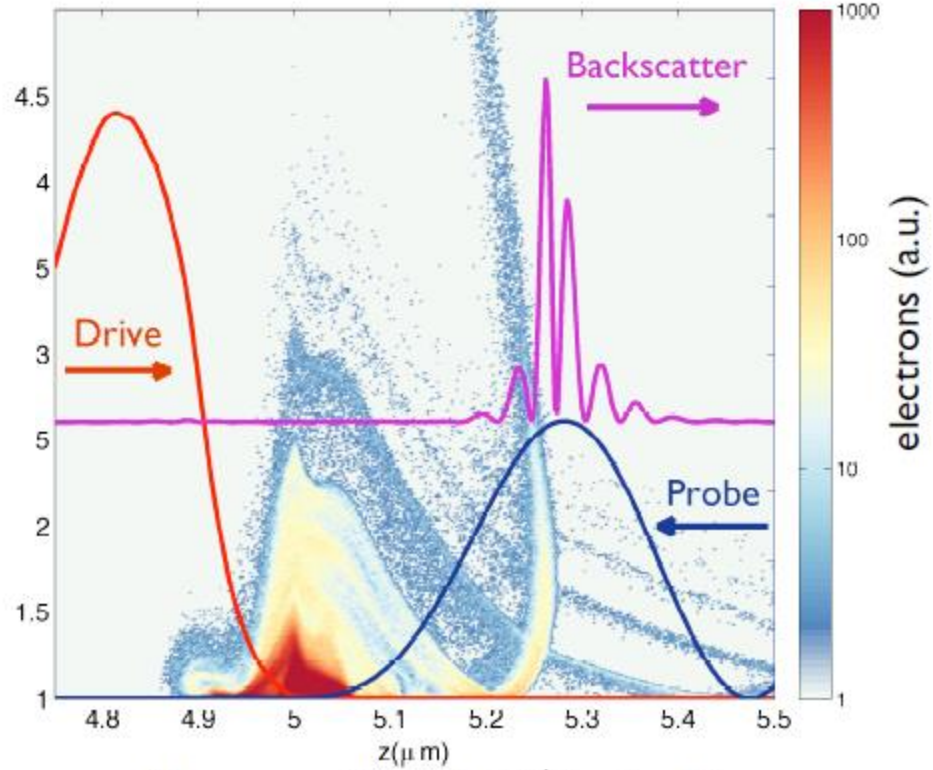
generation of dense (n_e~1-10n_c), attosecond short (~10nm thin) relativistic electron bunches

Kiefer, et al. (2013). Nat Commun **4**: 1763 (in collaboration with QUB,RAL)

Frequency-upshift from Flying Mirrors

<u>Setup:</u>





(frequency filtered: $\omega/\omega_L > 5$)

<u>For a monochromatic mirror:</u>

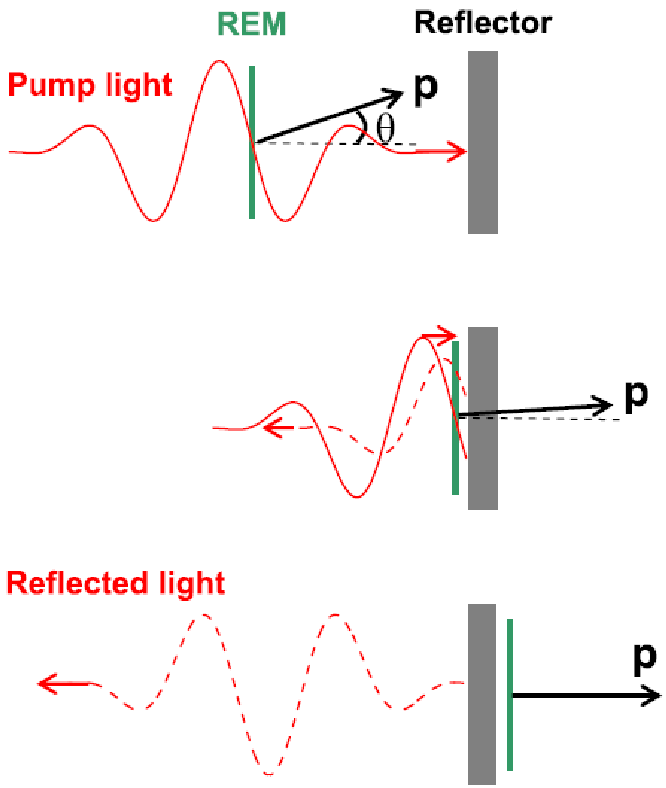
$$\omega_r = (1+\beta_z)^2\gamma_z^2\omega_L \qquad \gamma_z = \frac{1}{\sqrt{1-\beta_z^2}}$$

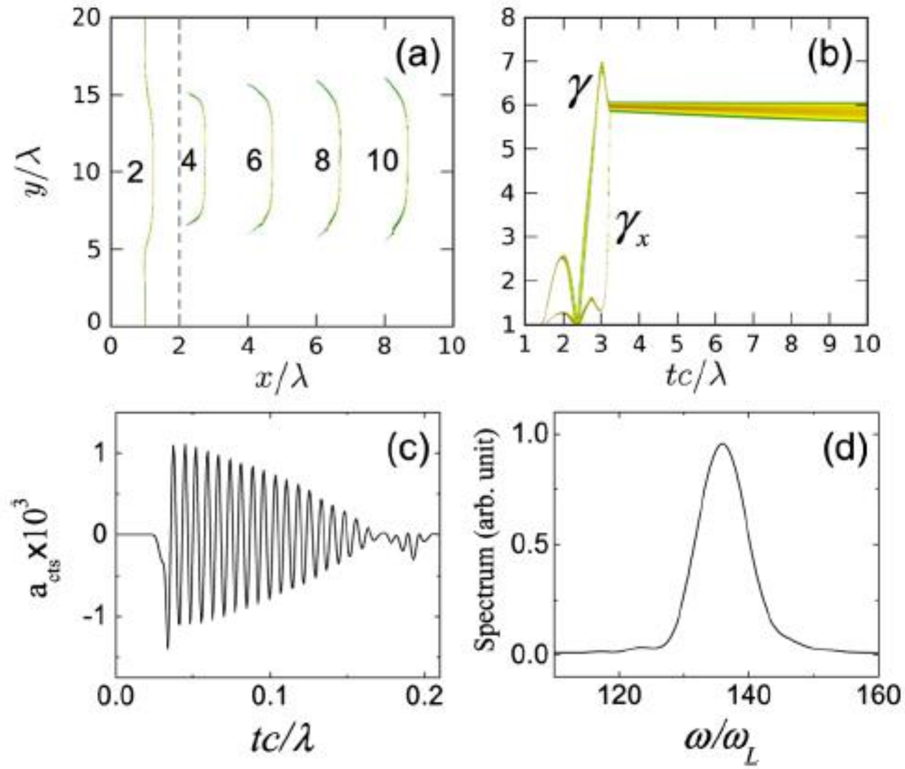
γ_z : factor of the mirror structure

$$=> \omega_{r,max} \sim 14\,\omega_L$$

Kiefer, et al. (2013). Nat Commun **4**: 1763 (in collaboration with QUB and RAL)

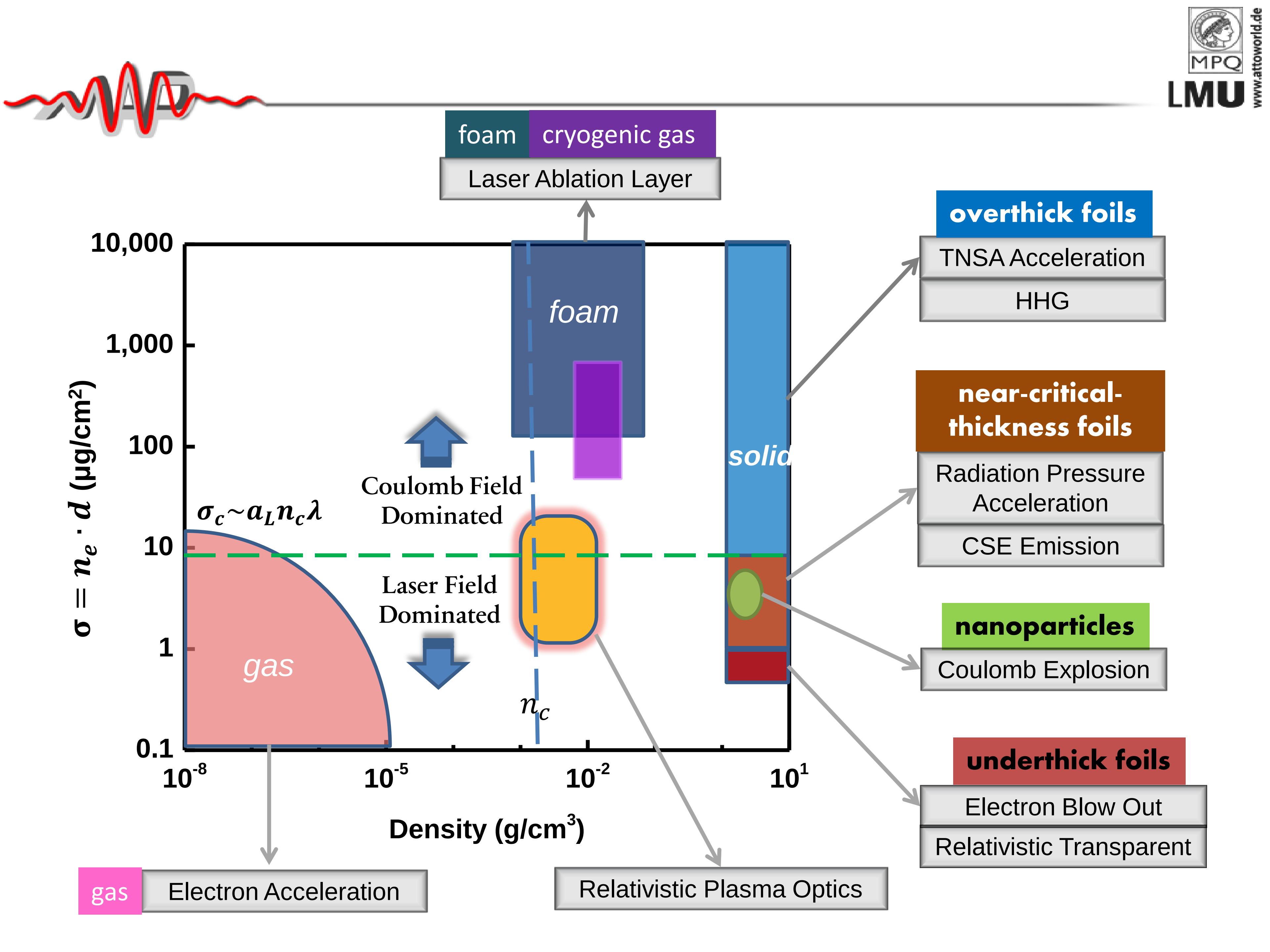
Thomsen Backscattering from Double Foil Targets





$$4\gamma_x^2 = 4\gamma^2/(1 + p_\perp^2) \approx 2\gamma.$$

$$4\gamma^2 = (4\gamma_x^2)^2 \sim 200$$

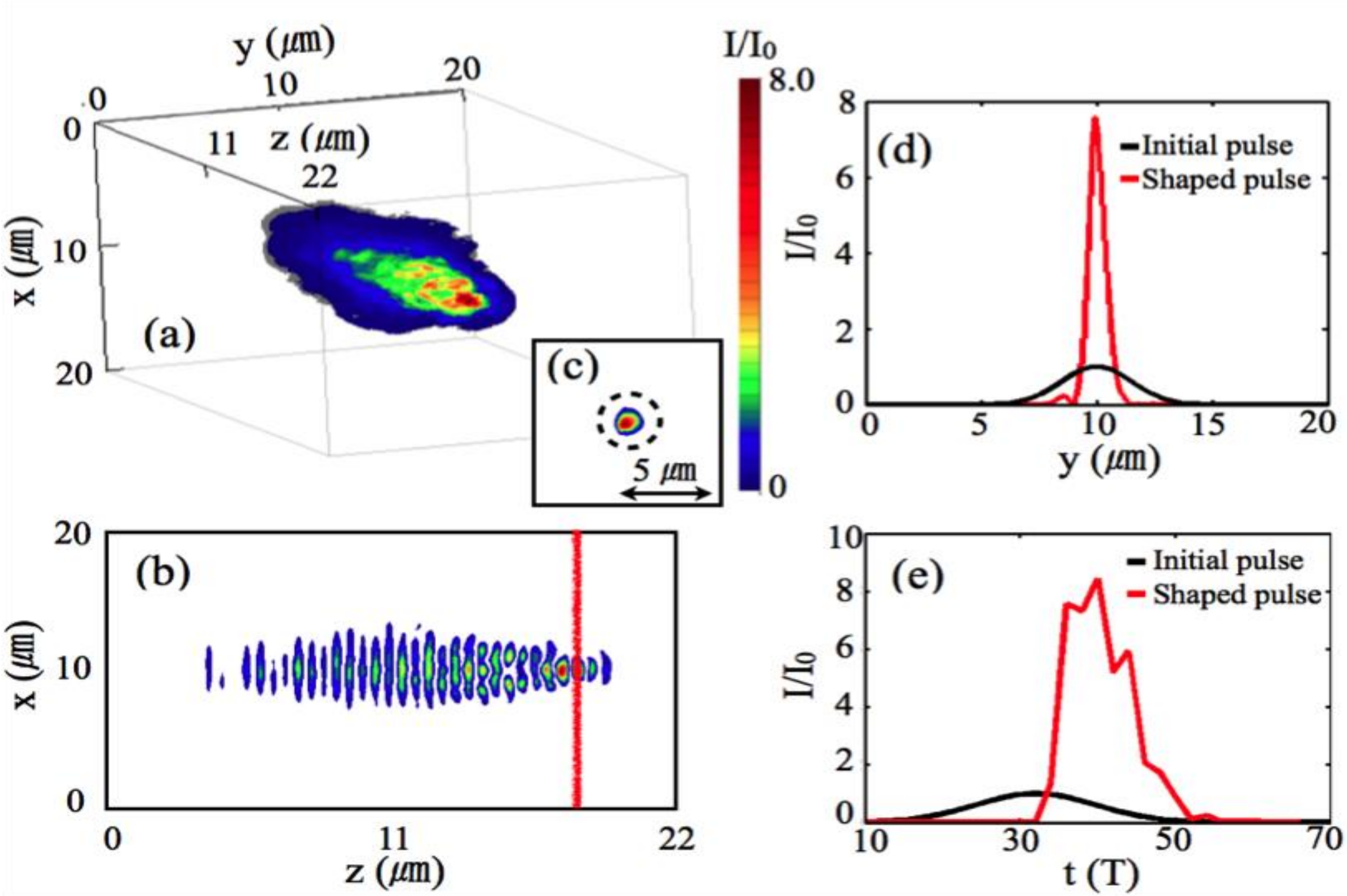


foam
cryogenic gas
Laser Ablation Layer
overthick foils
TNSA Acceleration
HHG
near-critical-thickness foils
Radiation Pressure Acceleration
CSE Emission
nanoparticles
Coulomb Explosion
underthick foils
Electron Blow Out
Relativistic Transparent
gas
Electron Acceleration
Relativistic Plasma Optics
10,000
1,000
100
10
1
0.1
10^{-8}
10^{-5}
10^{-2}
10^{1}
Density (g/cm^3)
$\sigma = n_e \cdot d$ (μg/cm^2)
$\sigma_c \sim a_L n_c \lambda$
Coulomb Field Dominated
Laser Field Dominated
foam
solid
gas
n_c
MPQ
LMU
www.attoworld.de

Self-focusing in Relativistic Plasma

	Theoretical Formula	$n_e = 10^{-2} n_c$ $a_L = 10$	$n_e = n_c$ $a_L = 10$
Refractive Index (η)	$[1 - n_e/(a_L n_c)]^{1/2}$	0.9995	0.95
Self-focusing Length (L_s)	$\sigma_L (n_c a_L / n_e)^{1/2}$	$32\sigma_L$	$3\sigma_L$
Focus Spot (σ_m)	$0.74\lambda (n_c a_L / n_e)^{1/2}$	19 µm	1.5 µm

Pulse Focusing and Shaping in NCD Plasma

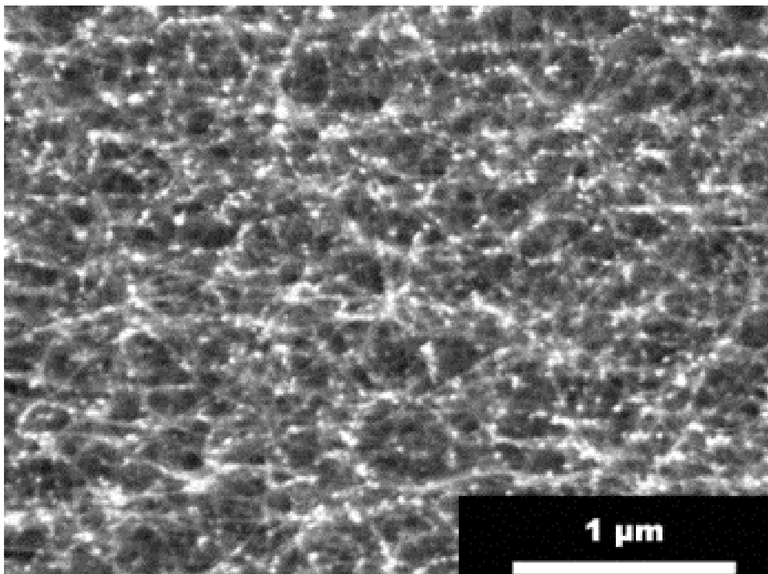


Enhancement on the Intensity

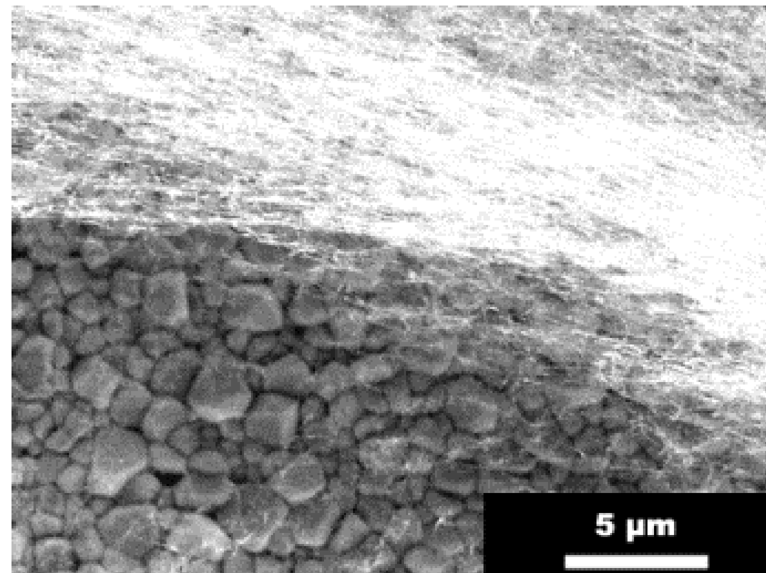
$I=2\times10^{20} w/cm^2 \rightarrow 1.5\times10^{21} w/cm^2$

Ultrathin Carbon Nanotube Foam

Freestanding UCNF



UCNF on DLC Foils

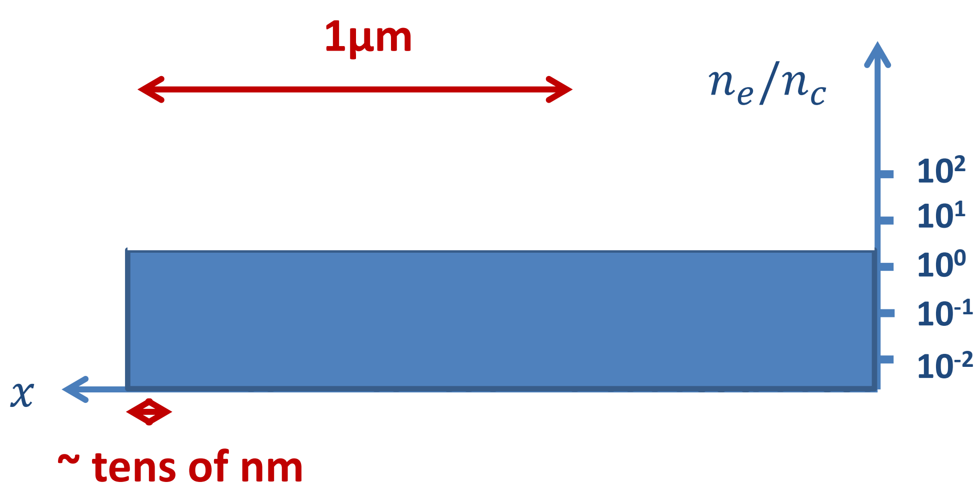


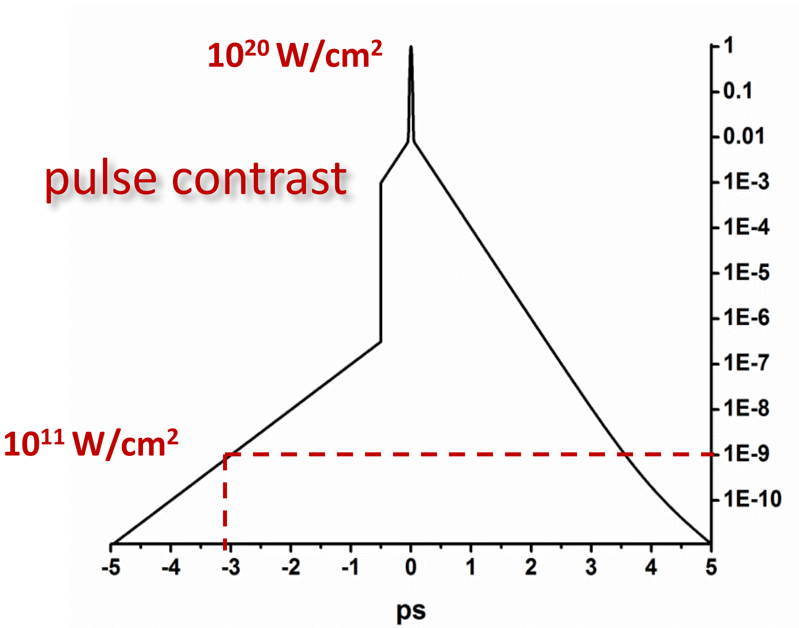
Density: ρ= 13~30 mg/cm^3

Thickness: d= 0.2~20 µm

n_e/n_c =2~5

NCD Plasma from CNUF





- ✓ Fully ionized
- ✓ Highly uniform
- ✓ Sharp boundary
- ✓ Thickness smaller deletion length
- ✓ Freestanding or deposited on any substrates

Acknowledgements

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