September 22, 2017, Chengdu

Summary of Laser Plasma Sessions

Zhengming Sheng

And all contributors of the Laser Plasma Sessions

Program committee for laser plasma

Zhengming Sheng (chair) (China)
Amita Das (co-chair) (India)
Shinsuke Fujioka (co-chair) (Japan)
Chang Hee Nam (co-chair) (Korea)

Yongkun Ding (China)
Cangtao Zhou (China)
G. Ravindra Kumar (India)
Yasuhiko Sentoku (Japan)
Kiminori Kondo (Japan)
Hyyong Suk (Korea)
Kitae Lee (Korea)
Heinrich Hora (Australia)
Donald Umstadter (USA)
Dimitri Batani (France)

A Glimpse of the Program

- 5 Plenary talks
- ✓ Xian-Tu He: The updated advance on inertial confined fusion program in China
- ✓ Jean-Luc Miquel: Laser MegaJoule status and program overview
- ✓ HyungTaek Kim: Overview on the development of laser electron acceleration and radiation sources with PW lasers
- ✓ Tomonao Hosokai: Status of Laser Wakefield Acceleration Research under ImPACT-UPL Program
- ✓ Yutong Li: Bring astrophysics to laboratories

- 27 Invited talks (including 8 talks for the Asian ICUIL)
- 6 Oral talks
- 4 Posters

A Glimpse of the Program (8 sessions)

Laser I [14:00-15:45], Place: S6 room in the 2nd Floor of West Building, Chair: Zheng-Ming Sheng

L-I1	Michel Koenig (25min)	Recent radiative hydrodynamic experiment in Laboratory Astrophysics at LULI.
L-I2	Byoung-ick Cho (25min)	Study of Warm Dense Plasmas with Ultrafast X-rays
L-I3	Jiaxiang Wang (25 min)	Boron laser fusion by plasma block ignition and avalanche reaction
L-O1	Tatiana Pikuz (15min)	New diagnostics developments for pump-probe experiments
L-O2	Yang Zhao (15min)	Experimental Study of K-shell Absorption Spectra in Dense Plasma at Shenguang II Laser Facility

Laser plasma II [16:20-18:25], Place: S6 room in the 2nd Floor of West Building, Chair: John Pasley

L-I4	Chi-hao Pai (25min)	Applications of laser-fabricated plasma structures in plasma nonlinear optics, ion acceleration and ultra-intense mid-infrared pulse generation
L-I5	Alessio Morace (25min)	Tailoring beam performance by interfering intense laser beamlets
L-I6	Hongbin Zhuo (25min)	High-order harmonic generation from laser interaction with a plasma grating
L-I7	S. Sengupta (25min)	On Wave Breaking of Relativistically Intense Longitudinal Waves in plasma
L-I8	Jianfei Hua (25min)	Controllable generation of high quality electron beams with very low absolute energy spread in a laser wakefield accelerator (LWFA) and the demonstration of wakefield snapshots using LWFA electron beams

Laser III [14:00-16:05], Asian ICUIL session, Place: S6 room in the 2nd Floor of West Building, Chair: Chang Hee Nam

L-I9	Ruxin Li (25min)	Progress of the SULF 10PW Laser Project
L-I10	Hiromitsu Kiriyama (25min)	10^{22} W/cm^2, 0.1 Hz, High-Contrast J-KAREN-P Laser Facility at QST
L-I11	Junji Kawanaka (25min)	Exploring High Pulse Energy, High Rep. Rate Laser in the Next Generation
L-I12	Suman Bagchi (25min)	Laser Plasma based Micrometer Size Mono-energetic Heavy Ion Accelerator
L-I13	Xueqing Yan (25min)	Efficient and stable ion acceleration from nanometer targets

Laser IV [16:30-18:10], Asian ICUIL session, Place: S6 room in the 2nd Floor of West Building, Chair: Hiromitsu Kiriyama

L-I14	Chang Hee Nam (25min)	Investigation of Superintense Laser-Matter Interactions with a 4 PW Laser
L-I15	Kitae Lee (25min)	Quasi-monoenergetic proton beams from a layered target irradiated by an ultra-intense laser pulse
L-I16	Yuqiu Gu (25min)	Status of fast ignition researches in LFRC
L-I17	Akifumi Yogo (25min)	Ion acceleration mechanism driven by multi-picosecond PW laser pulses

Laser V [14:00-15:45], Place: S6 room in the 2nd Floor of West Building, Chair: M. Murakami

L-I18	Min Chen (25min)	Laser wakefield based particle accelerator and radiation sources at SJTU
L-I19	Min Sup Hur (25min)	Realization of hypothetical plasma dipole oscillation leading to burst of coherent radiation
L-I20	Xiaomei Zhang (25min)	Particle-in-Cell Simulation of X-ray Wakefield Acceleration and Betatron Radiation in Nanotubes
L-O3	Seong G. Lee (15min)	Double Plasma Mirror System For the 4 PW Ti:Sapphire Laser at CoReLS
L-O4	Kai Huang (15min)	Electron Energy Spectrum Evolution during Magnetic Reconnection in Laser-Produced Plasma

Laser VI [16:20-18:25], Place: S6 room in the 2nd Floor of West Building, Chair: D. Batani

L-I21	João Jorge Santos (25min)	Strong quasi-static and transient fields driven by laser and the enhancement of the energy-density flux of charged particle beams
L-I22	Ke Lan (25min)	Progress in Octahedral Spherical Hohlraum Study
L-I23	Keisuke Shigemori (25min)	Diamond ablator for direct drive inertial confinement fusion targets
L-I24	Dong Yang (25min)	Investigating the hohlraum radiation properties through the angular distribution of the radiation temperature on Shenguang-III prototype
L-I25	Weimin Wang (25min)	Magnetically assisted fast ignition scheme for inertial confinement fusion

Laser VII [14:00-15:45], Place: S6 room in the 2nd Floor of West Building, Chair: Ke Lan

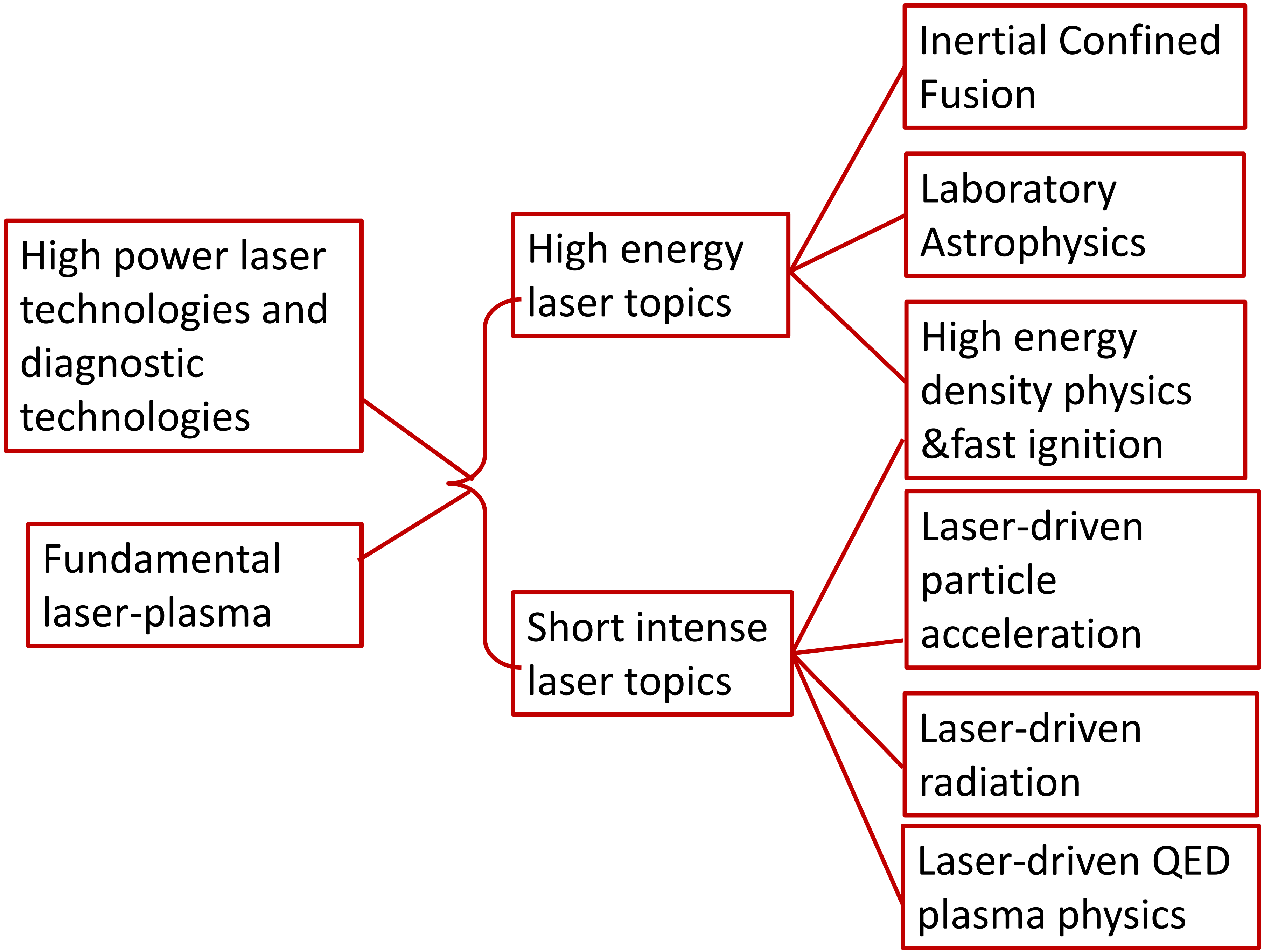
L-I26	Masakatsu Murakami (25min)	Quasimonoenergetic Proton Generation for Compact Neutron Sources
L-I27	Manchikanti Krishnamurthy (25min)	Acceleration of neutral atoms in laser produced plasmas
L-I28	John Pasley (25min)	Hydrodynamics Driven by Intense short-pulse lasers
L-O5	Baisong Xie (15min)	Accelerating and guiding carbon ions in laser plasma by mechanism of breakout afterburner with a tapered channel
L-O6	Dimitri Batani (15min)	Generation of high-pressures in aluminum by femtosecond low-energy laser irradiation

Laser VIII [16:20-18:25], Place: S6 room in the 2nd Floor of West Building, Chair: Hongbin Zhuo

L-I29	Guangyue Hu(25min)	Laser plasma evolution in external 10T magnetic field
L-I30	Bin Qiao (25min)	Brilliant gamma-ray emission from near-critical plasma interaction with ultraintense laser pulses
L-I31	Liangliang Ji (25min)	Near QED-regime of laser–plasma interaction
L-I32	Katarzyna Jakubowska (25min)	Refraction Index of Shock Compressed Water in the Megabar Pressure Range
L-I33	Yongsheng Huang (25min)	Laser Particle Acceleration, Radiation and Laser Nuclear Physics

Topics covered in the talks

- Inertial confined fusion physics and technologies, new concepts
- Laboratory astrophysics and high energy density physics
- Ultra-high power laser system development
- Laser plasma based particle acceleration (electrons, ions) and radiation
- Fundamental laser plasma physics (physics related with fs laser-driven shock waves, strong magnetic fields, nonlinear plasma waves, etc.)



High power laser technologies and diagnostic technologies
Fundamental laser-plasma
High energy laser topics
Short intense laser topics
Inertial Confined Fusion
Laboratory Astrophysics
High energy density physics &fast ignition
Laser-driven particle acceleration
Laser-driven radiation
Laser-driven QED plasma physics

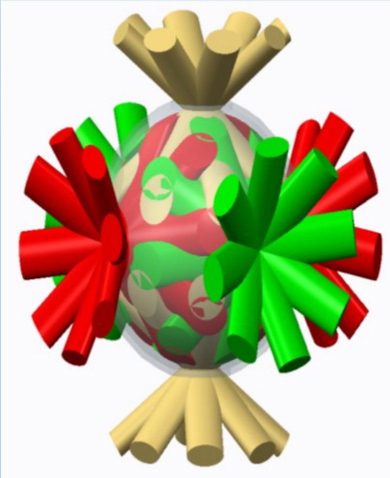
Inertial confined fusion physics and technologies, new concepts

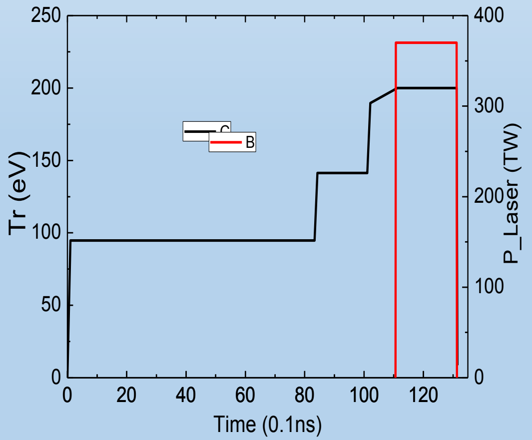
(new facilities, new schemes and concepts)

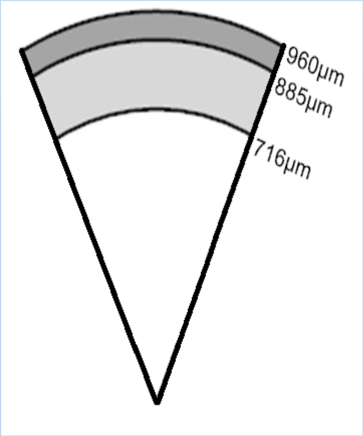
P1: Xian-Tu He @ The updated advance on inertial confined fusion program in China

SG-IV (2-3MJ), Direct-Indirect hybrid drive scheme

Hybrid drive (HD) approach for ICF combined the advantage of indirect drive (ID) and direct drive (DD) and discarded their shortcoming, and is performs in two phases:







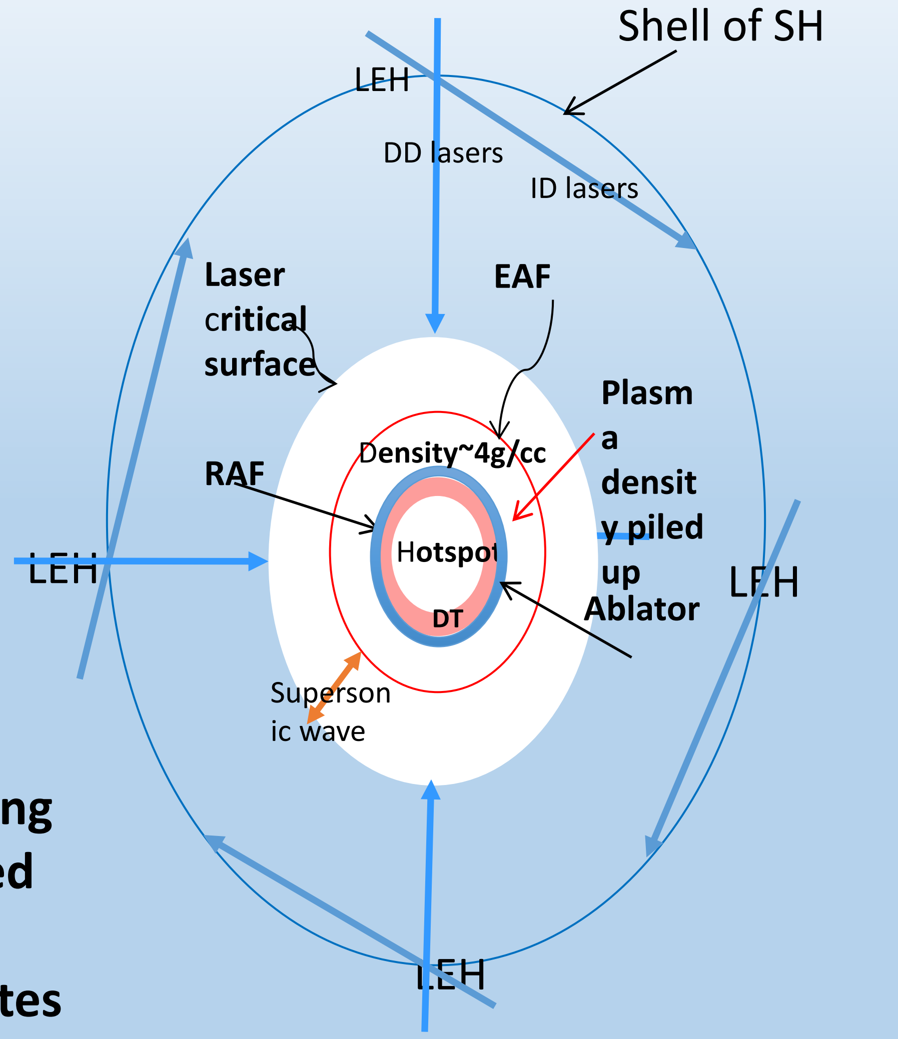
- Spherical hohlraum (SH) with six laser entrance holes (LEHs) and a layered capsule inside SH
- Typical driving source for ID T (black) and DD laser power (red)
- Cutting capsule

- **For the first phase:**

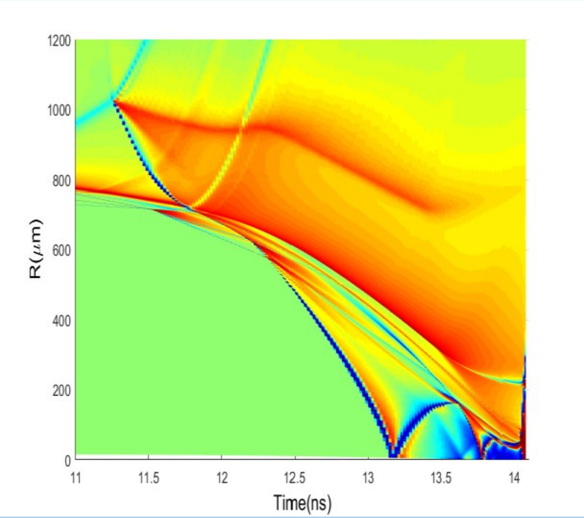
radiation temperature of T~200eV lower than that in traditional ID is generates by long pulse (~10 ns) ID lasers which irradiate to inner wall of SH through six LEHs, and ablates the surface of a layered capsule with fuel to drive a pre-compression via implosion dynamics, meanwhile, a long scale ID corona plasma is formed

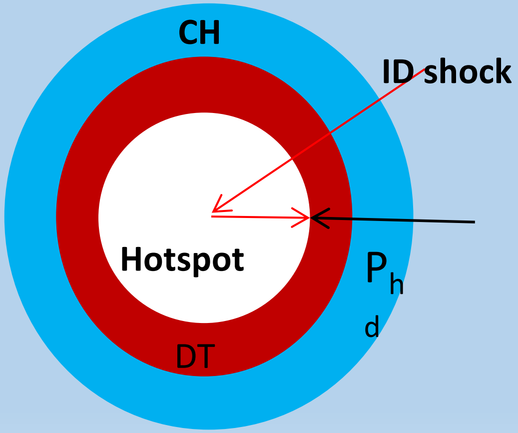
- **For the second phase.**

DD laser beams incident upon critical surface formed by ID corona plasma during last 2 ns of ID long pulse and are absorbed there. A supersonic-e-thermal wave is formed near critical surface and propagates in the ID corona toward radiation ablation front (RAF)



Such high plasma pressure drives a maximal implosion velocity V_{im} > 400km/s and stops the ID shock reflection, which rebounded from off-center of hotspot, at the hotspot interface. As a result, The HD shock suppresses hotspot deformation and hydrodynamic instabilities caused by the ID shock reflection at hotspot interface. The HD shock enters hotspot that is further heated and the non-stagnation and high-gain ignition occurs when the HD shock rebounded near hotspot center first reflects there.

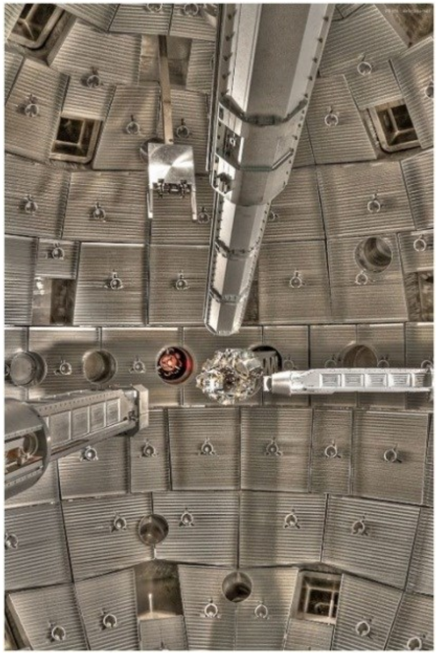




Laser Megajoule Status and Program Overview

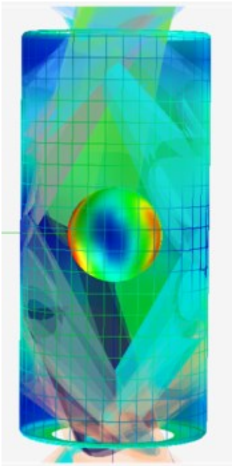
P13: Jean-Luc Miquel

LMJ status



- LMJ is part of the Simulation Program which combines physics models, numerical simulation and experimental validation
- 6 experimental configurations have been defined during the ramp-up of LMJ
- LMJ is now working in the 2nd configuration (2 bundles = 16 beams, 60 kJ, 4 diagnostics) since end 2016, and it provides good overall performances
- 3 other bundles are mounted and will be activated next year (3rd configuration, 150 kJ, 10 diagnostics)
- Three activities are performed at the same time :
  - Mounting of new bundles
  - Commissioning of the previous assembled bundles
  - Physics experiments
- The 1st step of nuclear commissioning is in progress (October 2017)

Program overview



- CEA is developing a thematic approach on LMJ, and has defined 8 experimental topics for the Simulation Program
- Several physics campaigns have been performed since 2014 and have addressed 3 of these topics.
- The obtained experimental results are in good agreement with the simulations
- About 10 experiments are planned till 2019 and will addressed 6 different topics
- The first implosions with D_2+Ar capsules are planned in 2019

Laser Megajoule Status and Program Overview

PETAL status academic access to LMJ-PETAL

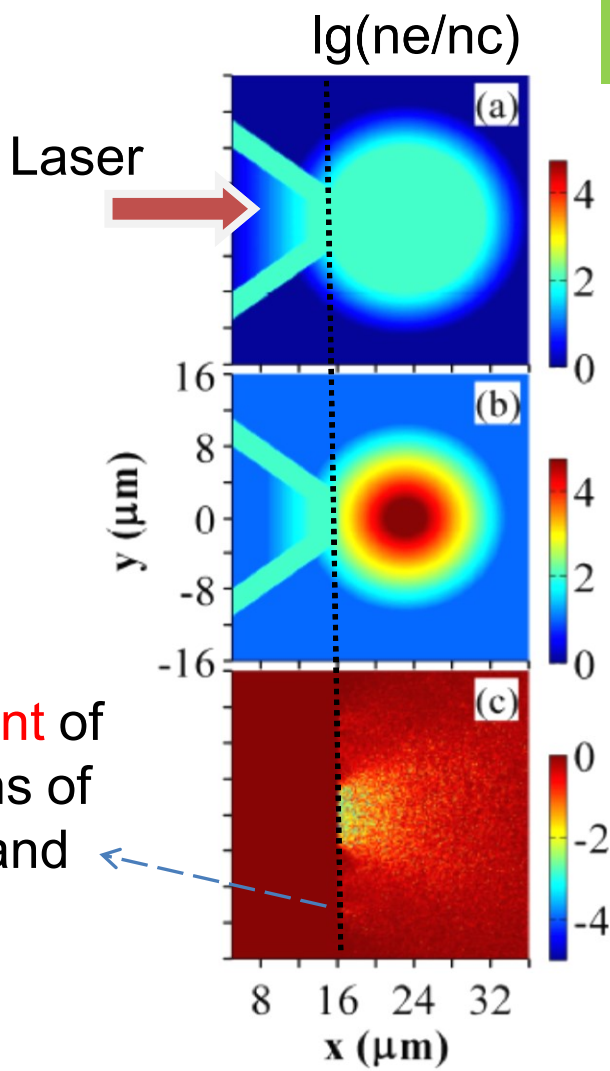
- PETAL, a multi-PW beam coupled to LMJ, will offer the opportunity to study a wider field of physics
- A record of 1.2 PW (840 J – 700 fs) has been obtained in 2015.
- Pulse duration has been improved (570 fs) and should bring the power to 1.8 PW

Academic access to LMJ-PETAL

- 2 call of proposals for 2017-2020 have received a great success (25 proposals)
- 6 experiments have been selected by the international scientific advisory committee
- LMJ-PETAL is ready for the first international academic experiments in December 2017

Proposal of two-system PIC for the whole FI heating study

L-I 25: W.M. Wang (IoP, CAS)



Conventional PIC system (maximum of ne =200 nc)

Hybrid PIC system (real density profile ne up to 54000 nc = 300g/cm^3 for tritium target)

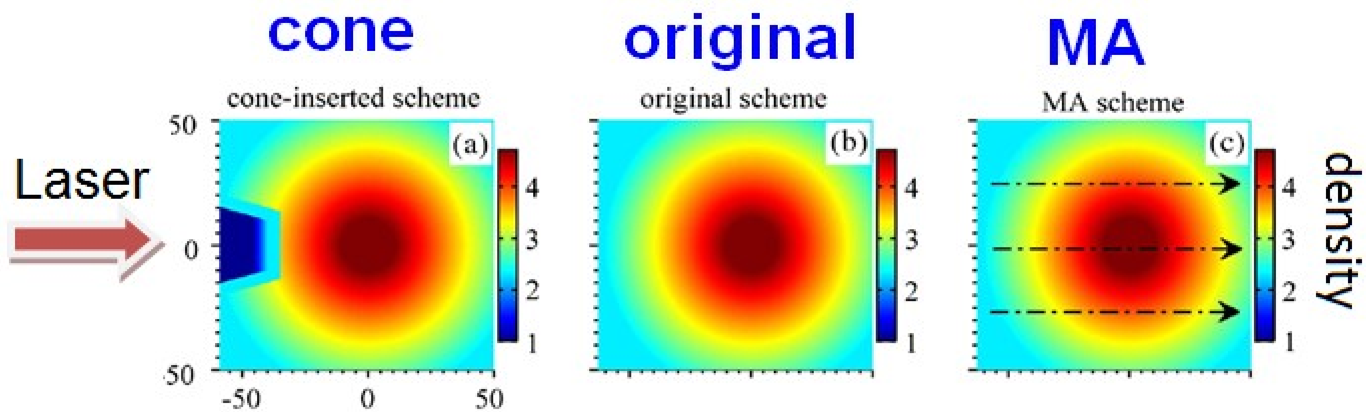
Fast electron current (J_{fx})in the hybrid system

Injection point of fast electrons of E>0.1MeV and px>0.45mc (50keV)

Wang, Gibbon, Sheng and Li, Phys. Rev. E 91, 013101 (2015)

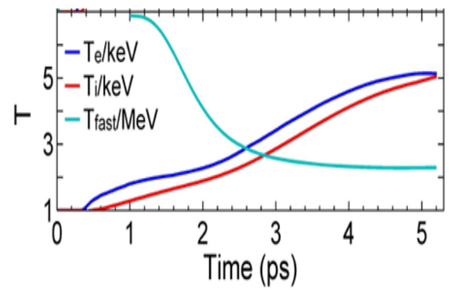
Magnetically assisted (MA) scheme with cone-free target

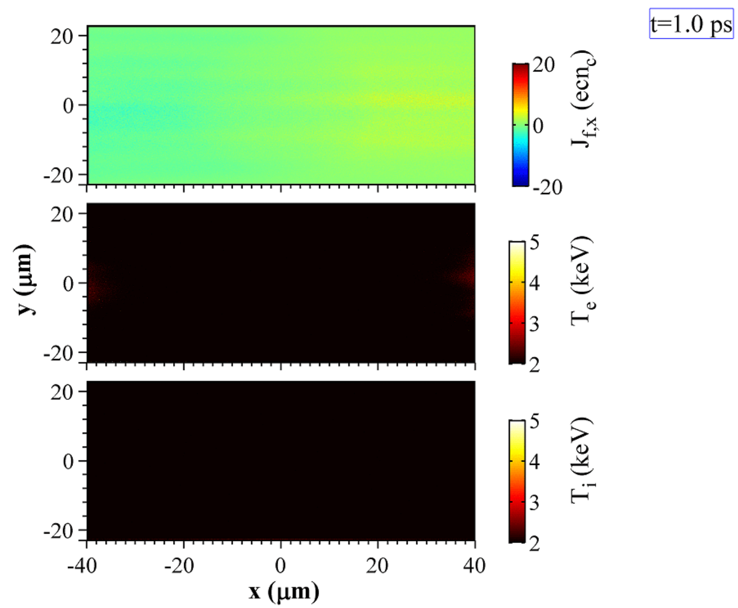
MA scheme can bring much higher laser-to-core coupling than the cone



Laser-to-core coupling **6%** | **2%** | **14%**

Two-system PIC simulations show: via MA, two counter-propagating lasers of 28kJ and 5 ps can heat the target core >5kev, reaching an ignition temperature





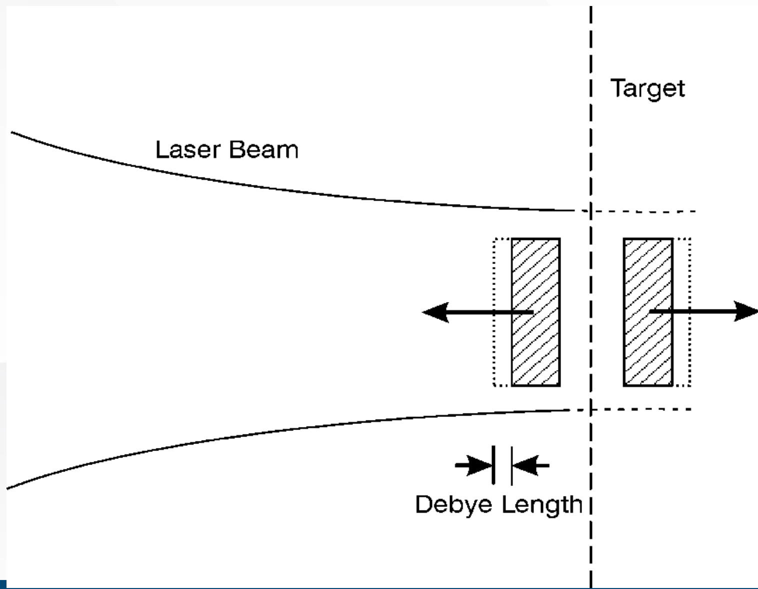
W.-M. Wang et al., PRL 114, 015001 (2015)
W.-M. Wang et al., arXiv:1606.02437

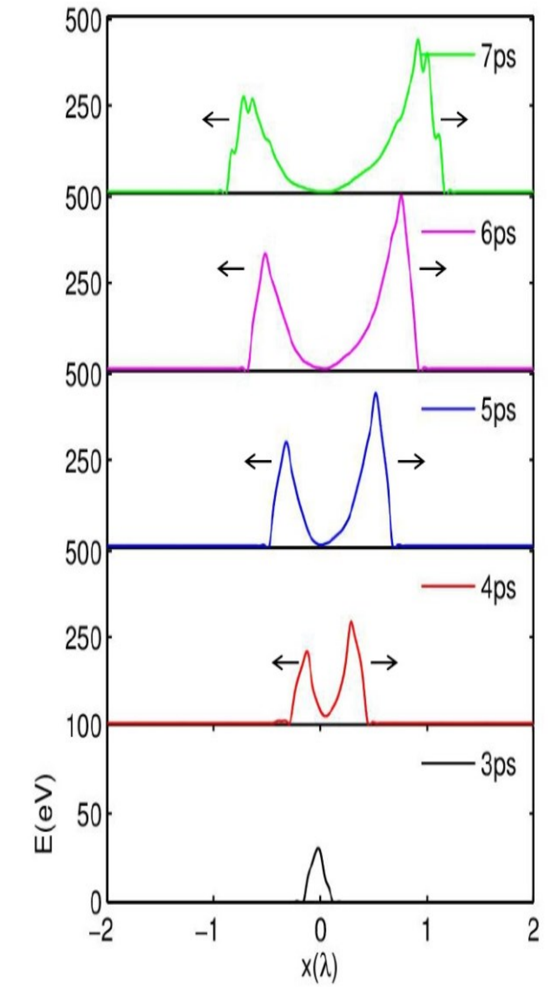
Boron laser fusion by plasma block ignition

Wang and Heinrich Hora-

L-I3: J.X. Wang

- The neutral plasma block acceleration by intense picosecond (10^{16}W/cm^2) been demonstrated by PIC simulation for the first time.



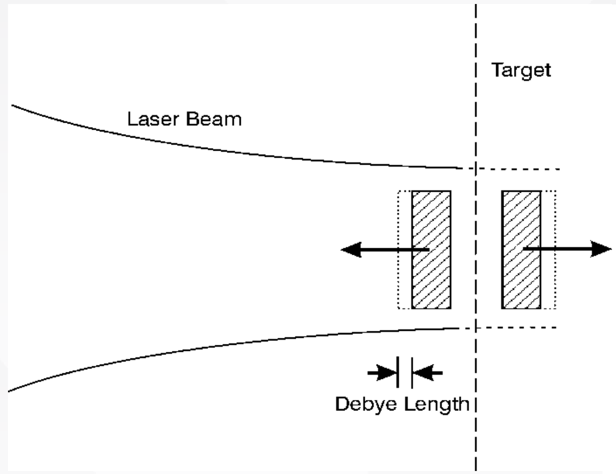


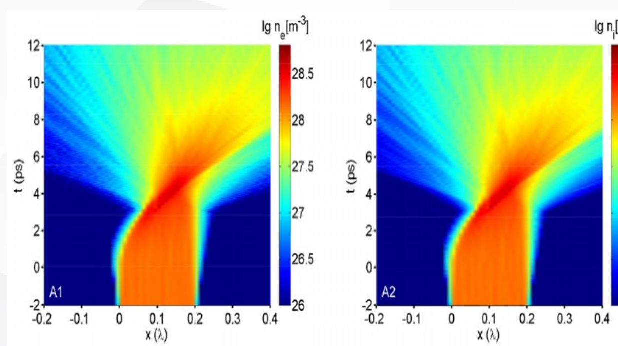
Boron laser fusion by plasma block ignition

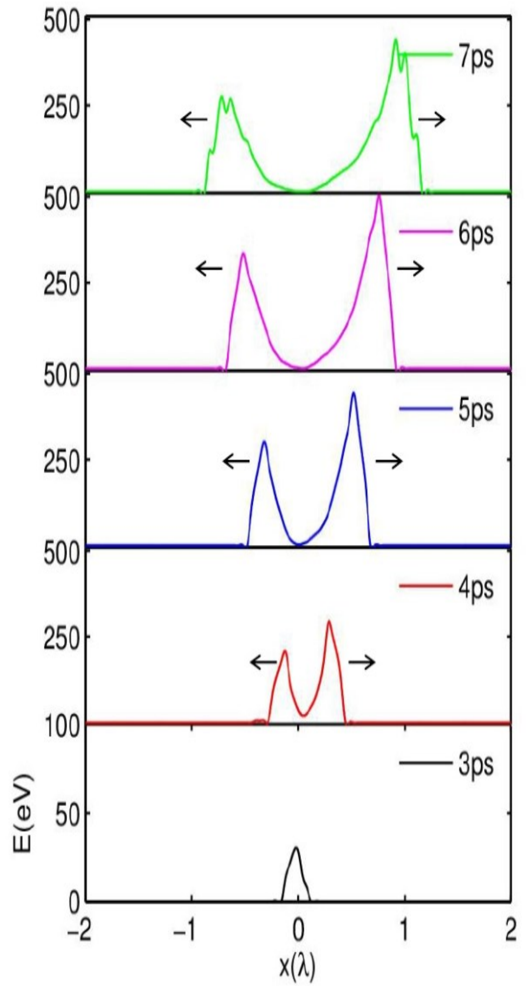
-Jiaxiang Wang and Heinrich Hora-

L-I3: J.X. Wang

- The **neutral plasma block acceleration** by intense picosecond (10^{16}W/cm^2) been demonstrated by **PIC simulation for the first time.**







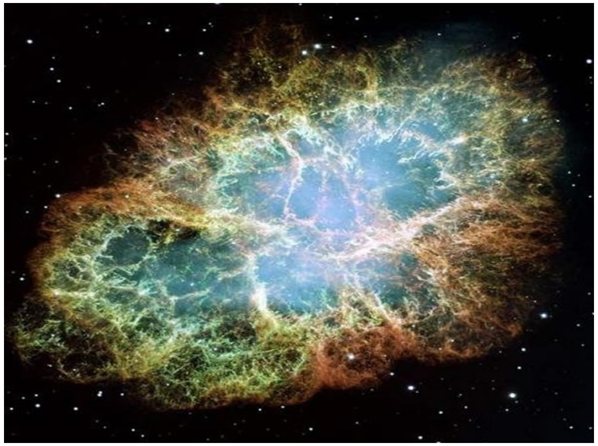
EAST CHINA NORMAL UNIVERSITY

Laboratory astrophysics and high energy density physics

(radiative shocks, hydrodynamic instabilities, warm dense matters, strong magnetic field effects, and diagnostic, etc.)

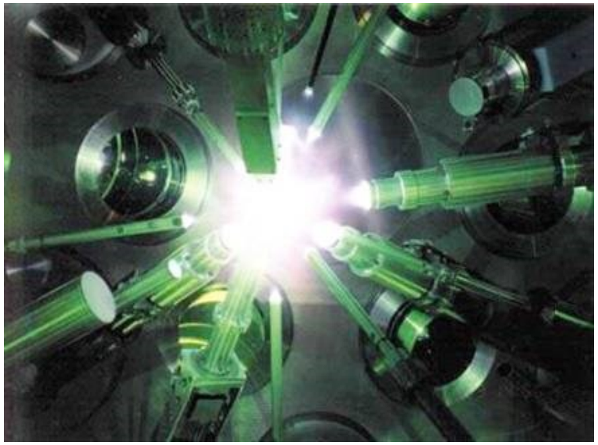
Bringing astrophysics to laboratory

Astrophysics



Astronomical observation is passive, far-distanced, and uncontrollable

Laboratory

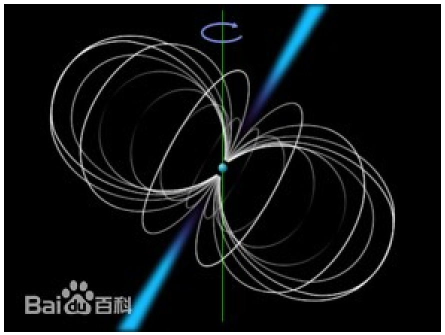


Experimentally studying astrophysics with the intense laser-driven extreme conditions in lab.

Space and time scaling

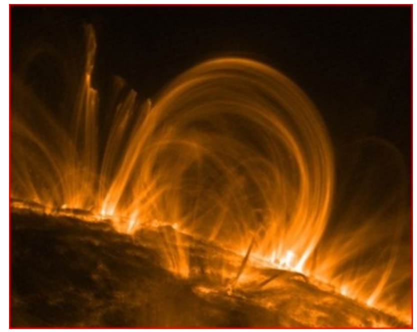
P30: Yutong Li

Typical results of laboratory astrophysics we have obtained



Strong B fields
in universe

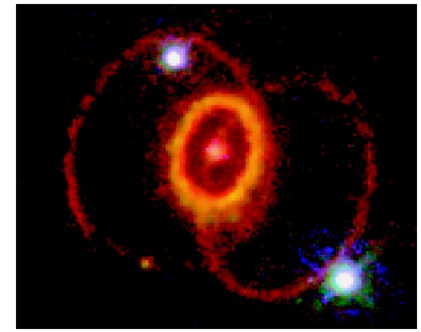
APL 107, 261903
MRE 1, 187



Magnetic reconnection
in solar-earth space

Nat. Phys. 6, 984
PRL 108, 215001
AJPS 225, 30

Highlighted by
Nature China



Collisionless shocks
in supernova remnants

New J. Phys. 13, 093001
Sci. Rep. 7, 42915
Sci. Rep. 6, 27363

Highlighted by
Nature Photonics

P30: Yutong Li

P30: Yutong Li

Summary

Observation + **Experiment**

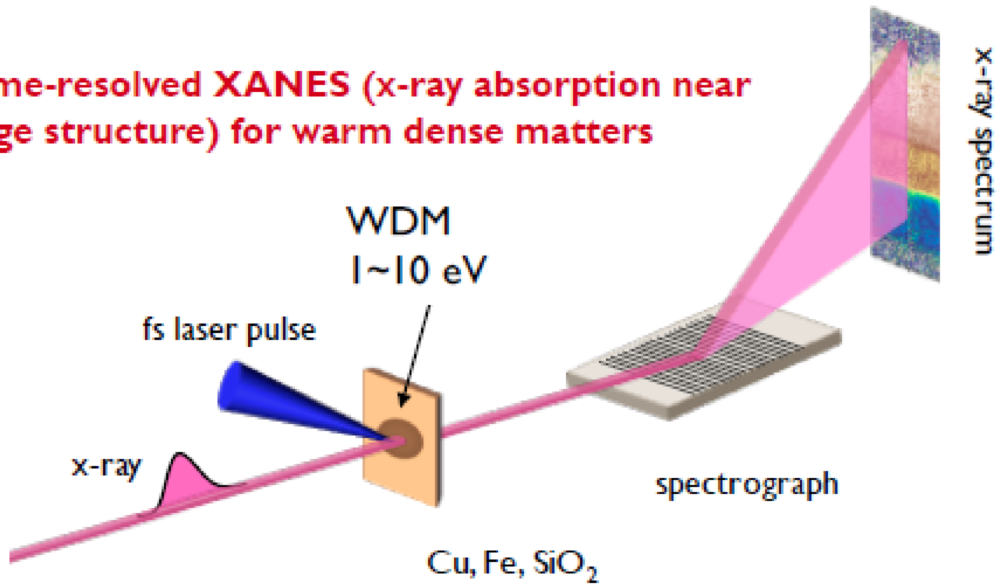
- **Strong B fields ~hundreds T – kiloT can be obtained with intense lasers.**
- **Laser-driven magnetic reconnection has been constructed.**
- **We have studied the collisionless shocks generated in the interactions of two counter-streaming flows. Filaments probably due to Weibel-type instability are observed.**

Study of Warm Dense Plasmas with Ultrafast X-rays

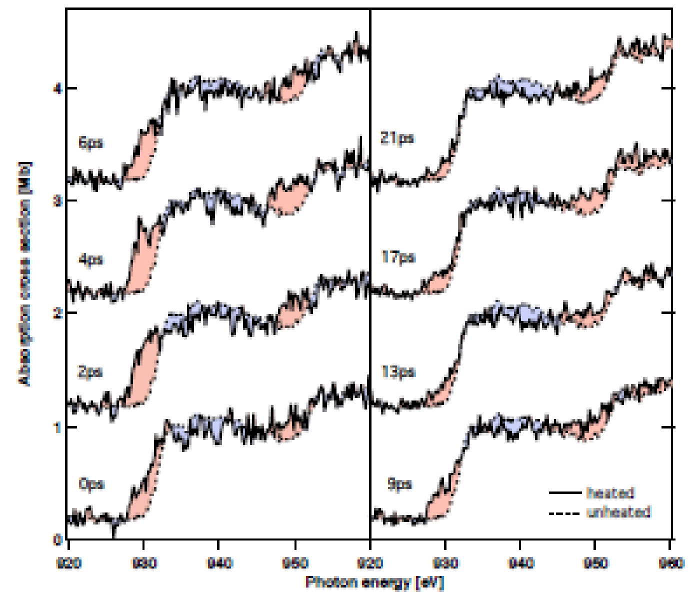
Byoung-ick Cho (bicho@gist.ac.kr)

L-12

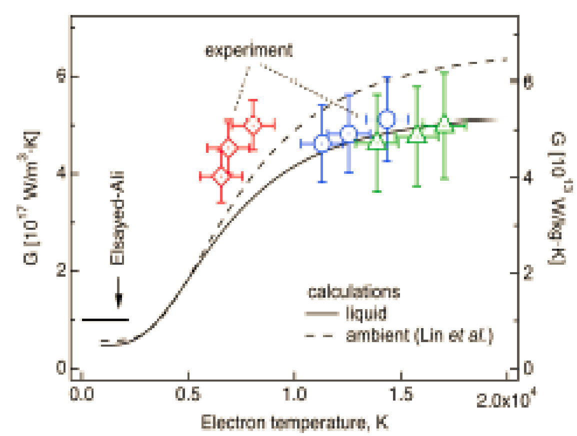
Time-resolved XANES (x-ray absorption near edge structure) for warm dense matters



WDCu, L-edge measurement



Electron-ion relaxation in WDCu



Warm dense Cu:

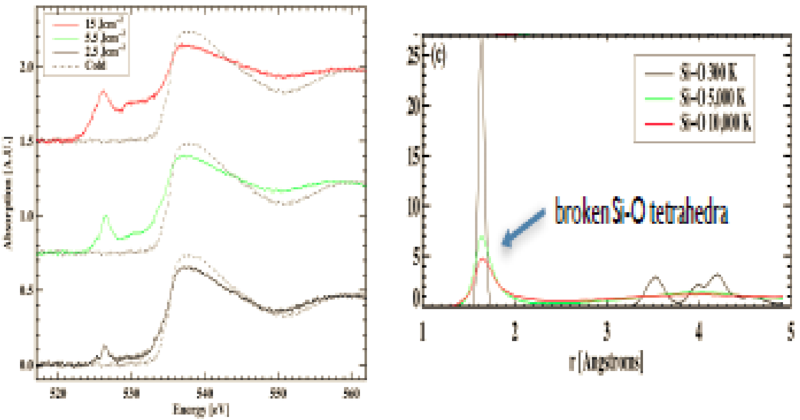
- $L_{2,3}$ – XANES measurement with 2ps resolution
- Temporal evolution of WDCu has been determined by comparing MD-DFT calculations with XANES measurement
- Enhanced electron-phonon couplings of noble metal in WD condition have been experimentally determined

Study of Warm Dense Plasmas with Ultrafast X-rays

Byoung-ick Cho (bicho@gist.ac.kr)

L-I2

WDSiO$_2$, O K-edge measurement & Radial distribution function



Warm dense SiO$_2$

- Electronic states associated with broken Si-O bonding during the insulator-metal transition are examined.
- T_e and T_i effects on O K-edge XANES spectrum has been investigated.

Strong quasi-static and transient fields driven by laser and the enhancement of the energy-density flux of charged particle beams

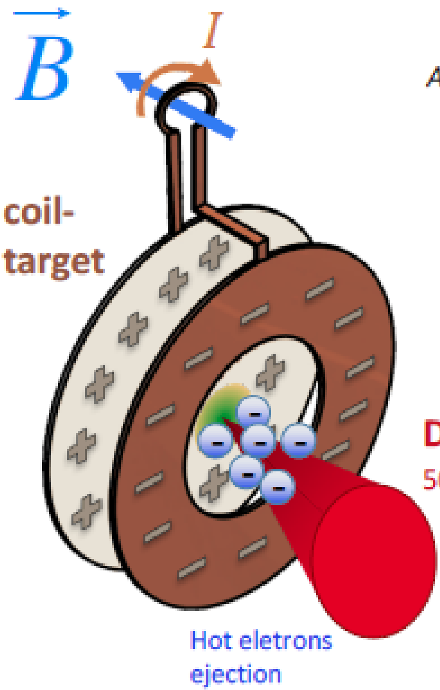
João Jorge Santos (joao.santos@u-bordeaux.fr)

CELIA

université BORDEAUX

L-I 21 J J Santos

➡ Magnetostatic-field on the excess of 0.5 kT from ns laser-driven diode



At the coil center :

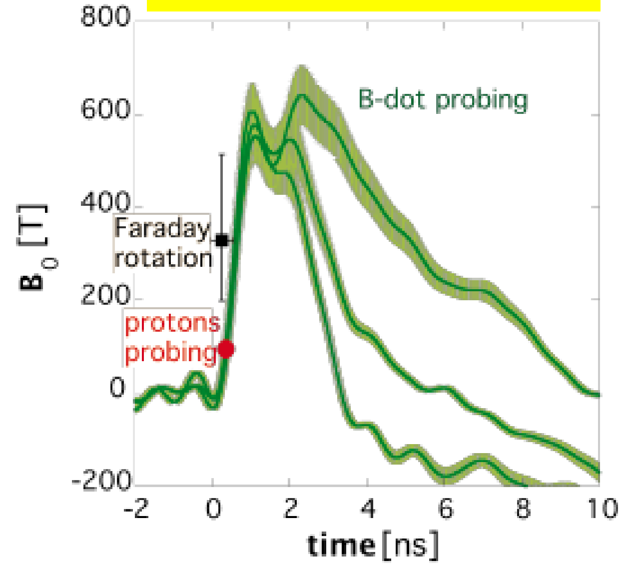
$$B_0 \approx \frac{\mu_0 I}{2a} \sim 600\ \mathrm{T}$$

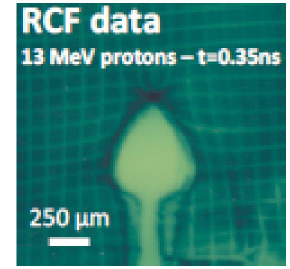
250 kA

coil radius = 250 µm

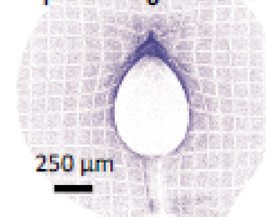
Driving laser

500 J, 1 ns, 10^{17} W/cm^2

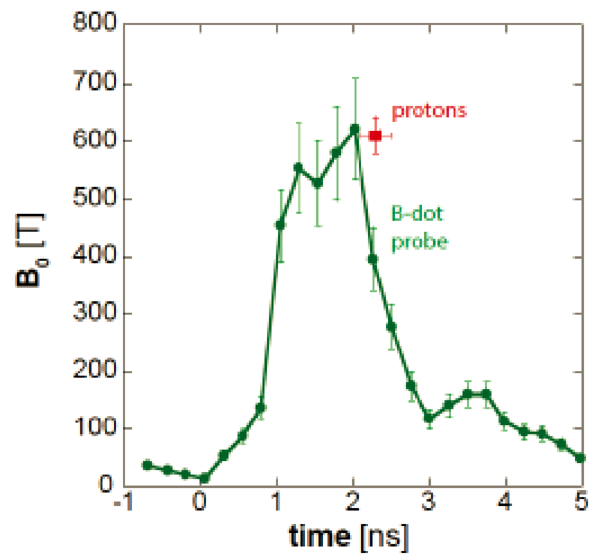




Simulation pour B_0 = 95 T



J.J. Santos *et al.*, New J. Phys. 2015



K.F.F. Law *et al.*, Appl. Phys. Lett. 2016

- ✓ **Reproducible B-field peak and rise-time**
- ✓ **Few ns duration**
- ✓ **Magnetized volume of 1 mm³** (for a = 250µm)
- ✓ **Compact, open geometry, suitable for laser-plasma experiments**

Strong quasi-static and transient fields driven by laser and the enhancement of the energy-density flux of charged particle beams

João Jorge Santos (joao.santos@u-bordeaux.fr)

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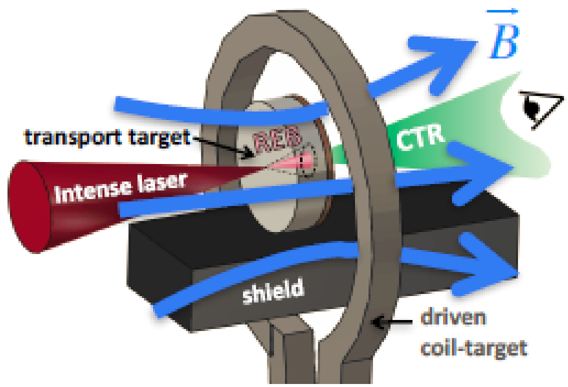
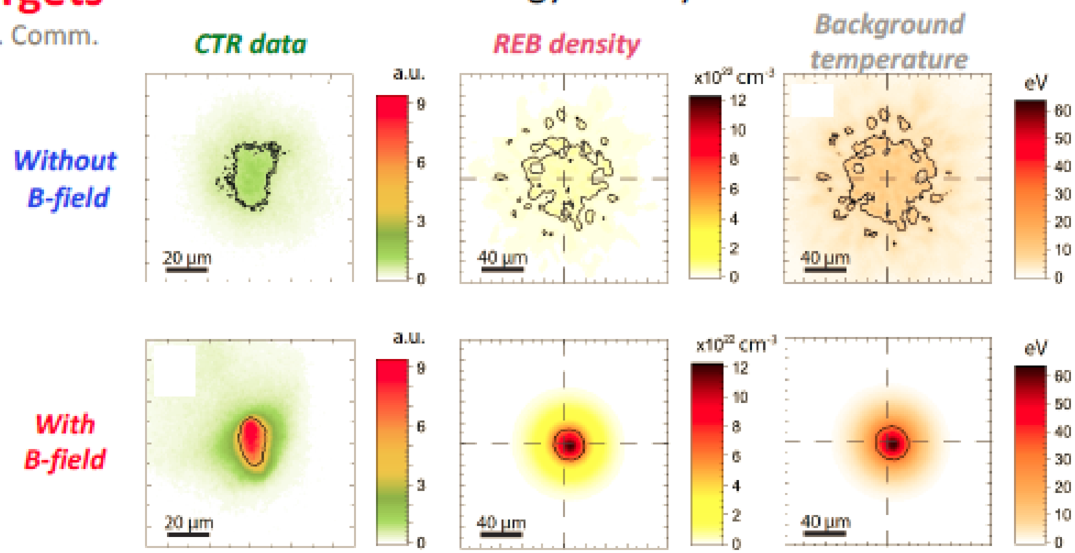
L- I 21 J J Santos

➡ Magnetic guiding of 10 MA current of MeV-electron beams in solid targets

M. Bailly-Grandvaux *et al.*, submitted to Nat. Comm.

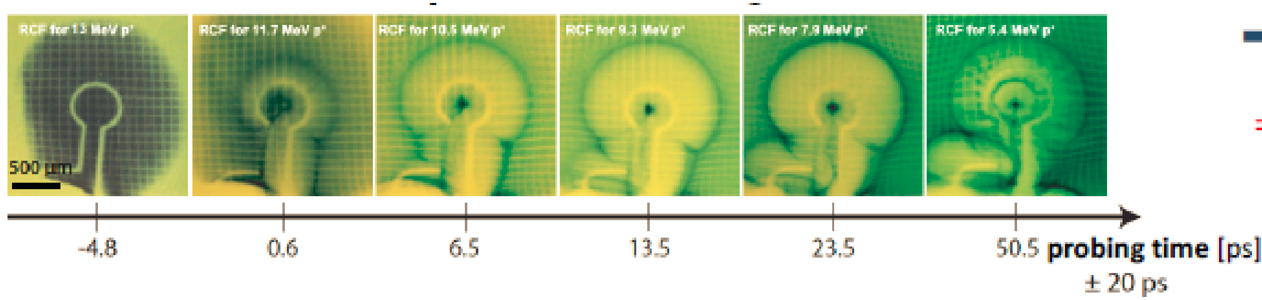
⇒ Unprecedented 5x enhancement of the energy-density flux





➡ 10^{10} V/m transient discharges driven by intense ps lasers

Space-time scales captured by proton-deflectometry



➡ Lens effect on up to 12 MeV protons lasts < 30 ps

⇒ **possible energy selection by tuning the lasers delay**

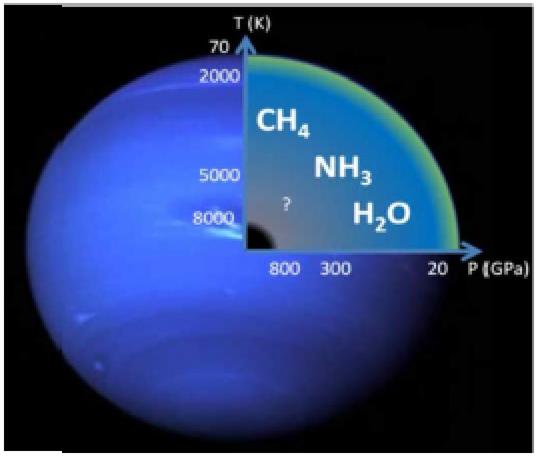
Refraction Index of Shock Compressed Water in the Megabar Pressure Range

L-I 32

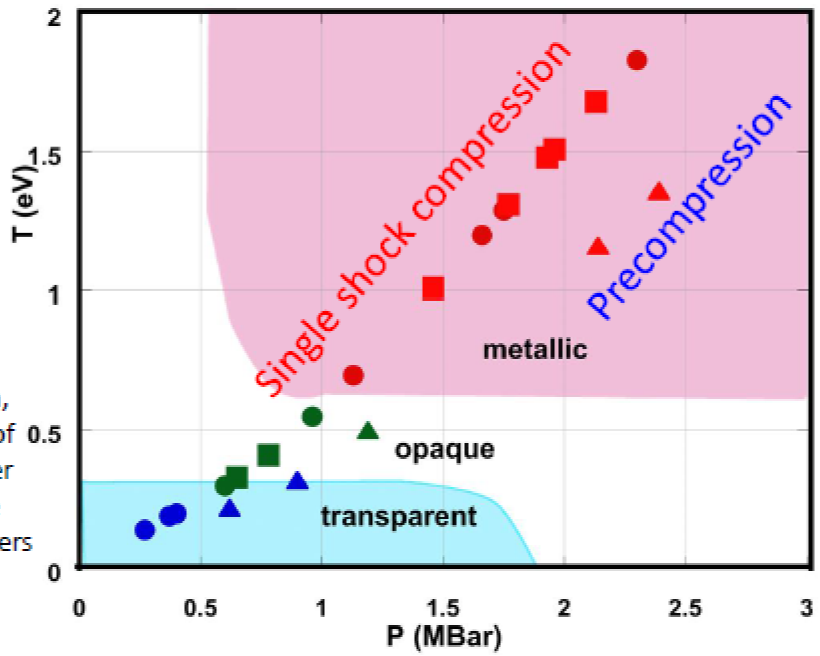
K. Jakubowska[1,2], D. Batani[1], J. Clerouin[3], B. Siberchicot[3]

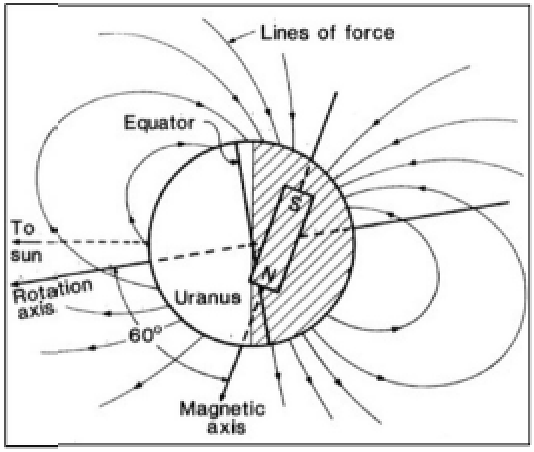
[1]Université Bordeaux; [2]IPPLM, Warsaw, Poland; [3]CEA/ DAM Arpajon

- ✓ Interest about H_2O justified by planetological research: origin of the magnetic fields of Uranus and Neptune



Experimentally measured behaviour of compressed water

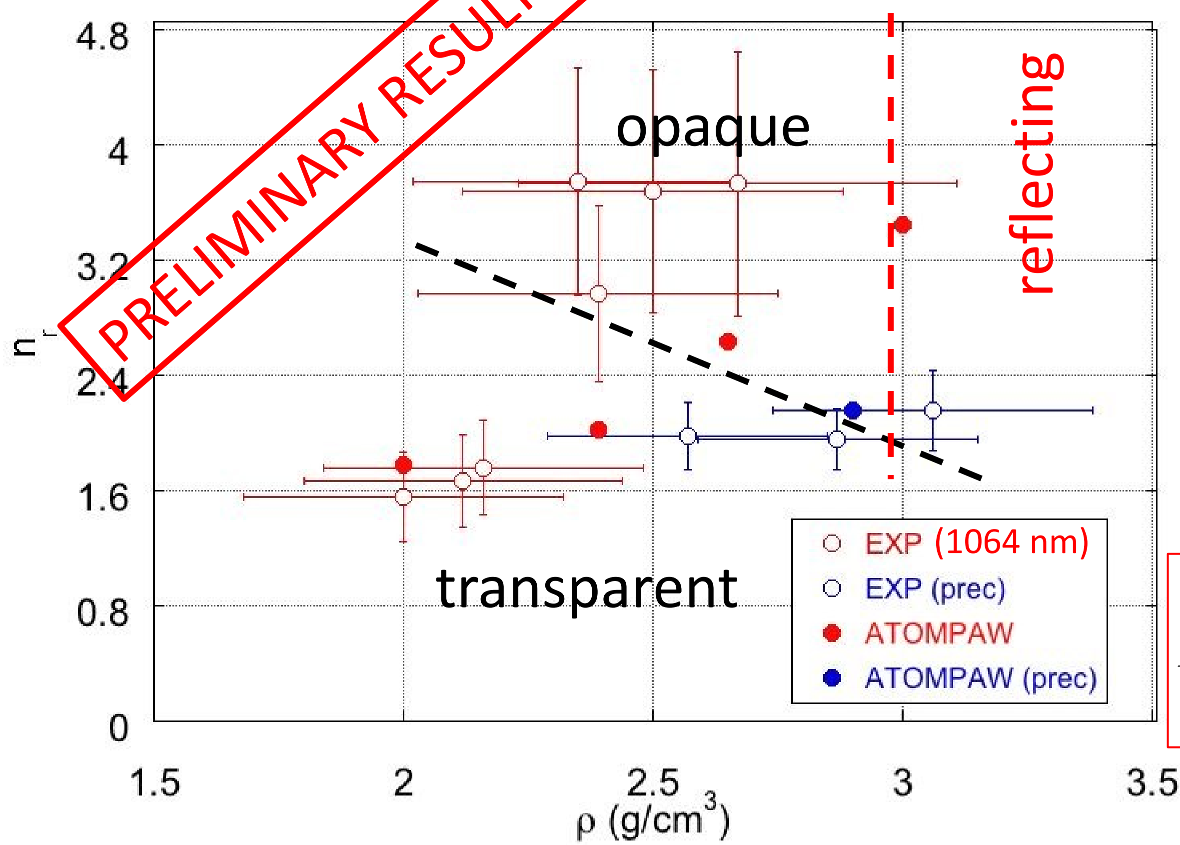




D. Batani, K. Jakubowska, et al. «Refraction Index of Shock Compressed Water in the Megabar Pressure Range» Europhysics Letters 112, 49901 (2015)

Experimental results on refraction index of compressed water and comparison with ab-initio calculations

Quantum molecular dynamic calculations performed with the ABINIT-ATOMPAW code, a common project of the Université Catholique de Louvain, Corning Incorporated, Commissariat à l'Energie Atomique, Université de Liège, Mitsubishi Chemical Corp (www.abinit.org)



Interpolations of simulation results with an extended Lorentz-Drude model can provide information on underlying physics (gap closure, ionization, …)

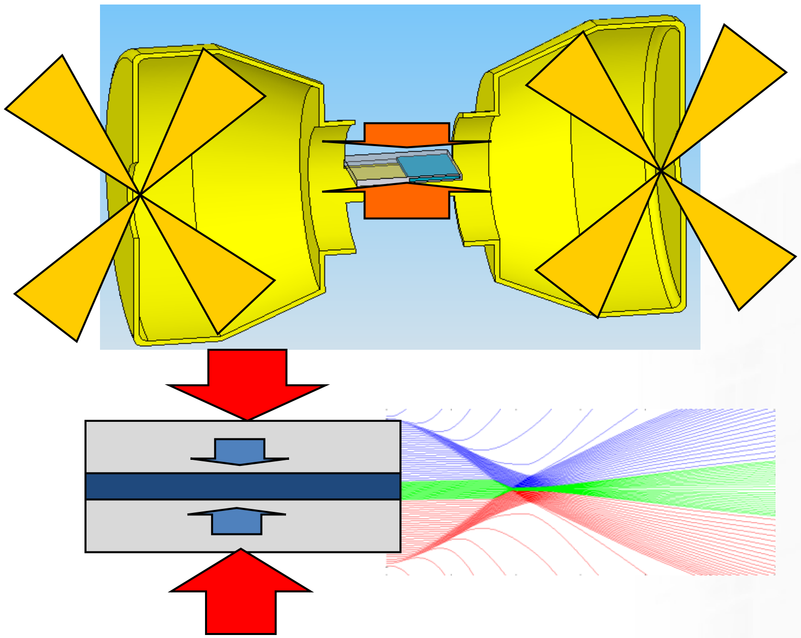
$$E_g(\rho,T) = E_{g0}\left[\frac{\rho_c-\rho}{\rho_c-\rho_0} - B\frac{T}{T_0}\right]$$

L-O2 Yang Zhao

Colliding-shock compression @ ShenGuang

◆Hohlraum Design

"Dog bone" gold hohlraum



J. Y. Zhang *et al.*, POP 19, 113302 (2012)

Y. Zhao *et al.*, PRL 111, 155003 (2013)

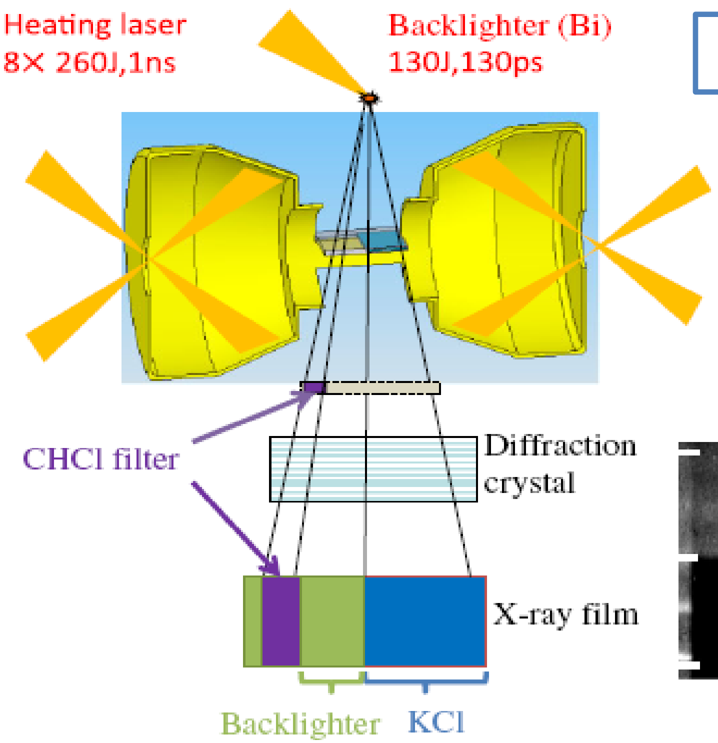
- near-Planck x-ray radiation.
- symmetrical inward shocks.
- two shocks simultaneously propagated into the layer and collided at the center.

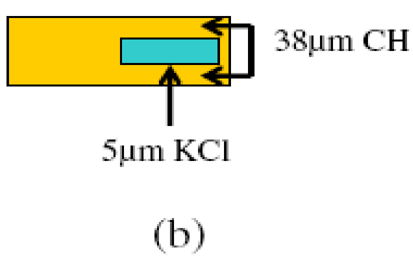
The central target was invisible to the laser-hitting point, and therefore, it stopped the M-band x rays from preheating and scattered laser lights ablating the sample.

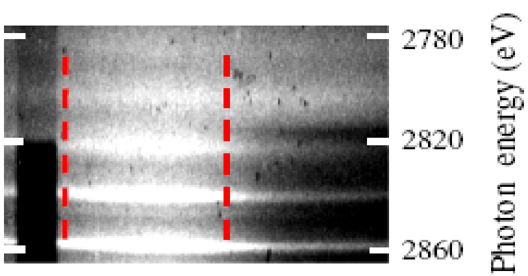
L-O2 Yang Zhao

Absorption Edge of Warm Dense Matter

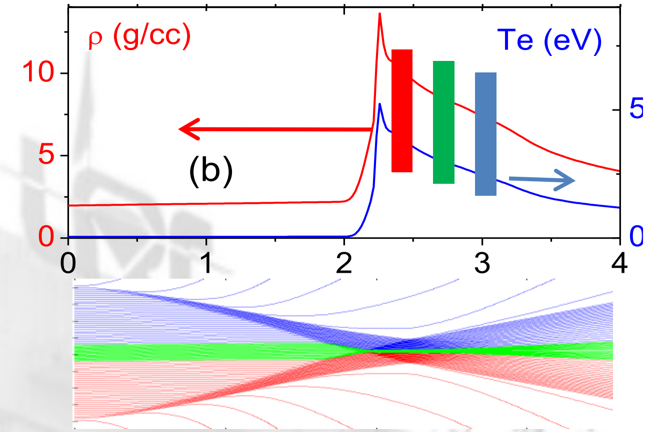
◆Experiment



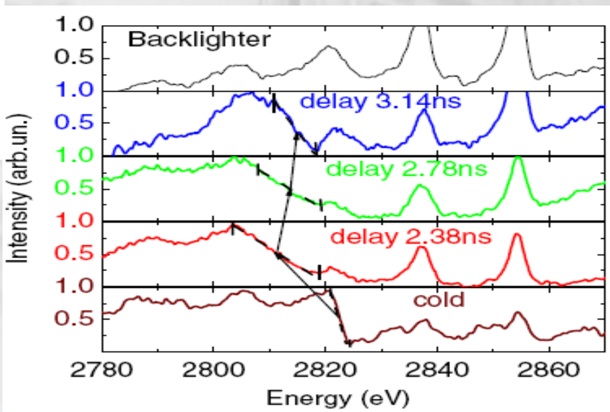




Hydrodynamic process



K-edge at three delays



➢The shifts and broadenings of the K-shell absorption edge for the compressed WDM are studied.

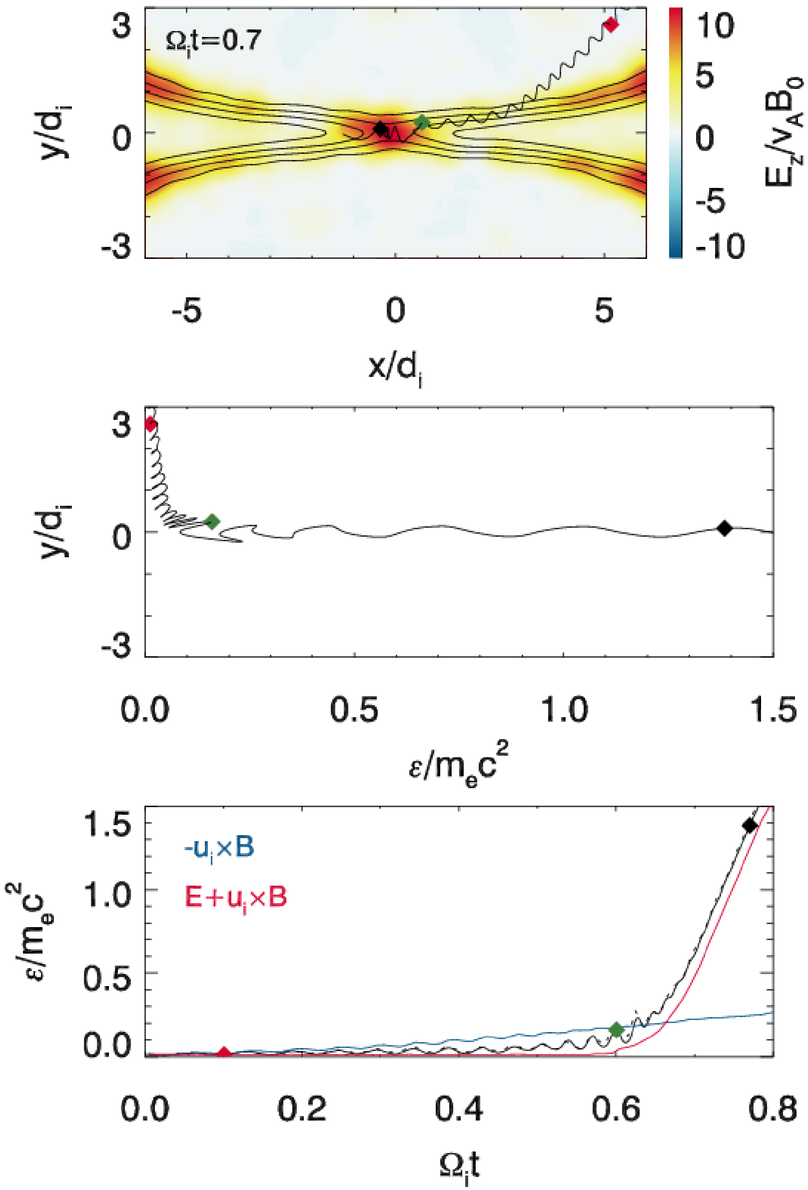
Electron Energy Spectrum in Magnetic Reconnection in Laser-Produced Plasma

中国科学技术大学
University of Science and Technology of China

L-O4: Kai Huang

- ➢ squeezing stage ($\Omega_i t = 0 - 0.6$)
- Electron get accelerated when reflected by the plasma bubbles
- Acceleration dominated by convective electric field
- Fermi acceleration

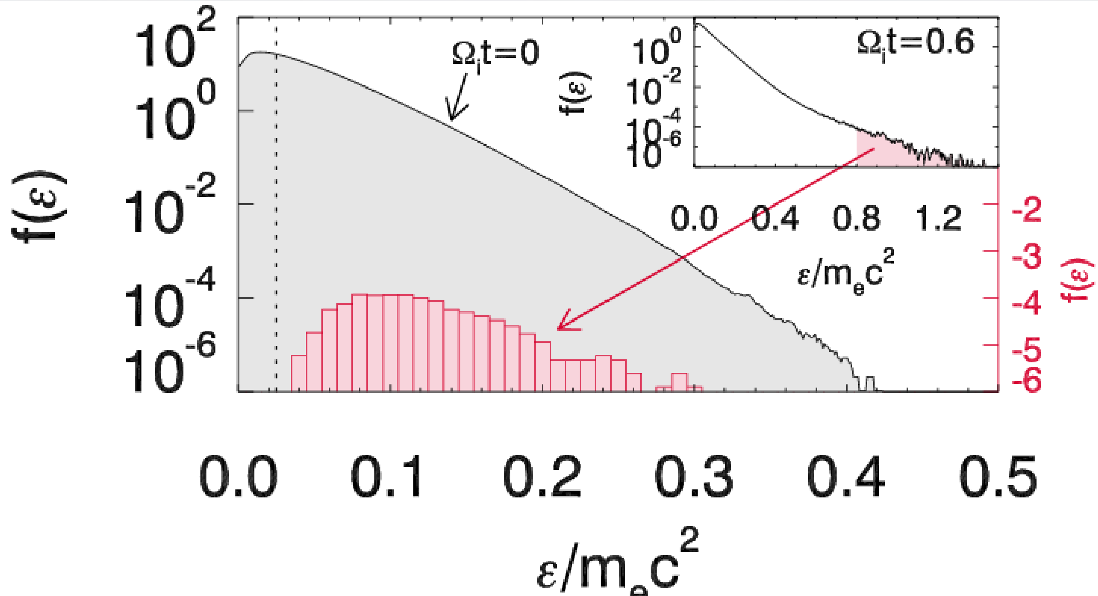
- ➢ reconnection stage ($\Omega_i t = 0.6 - 0.79$)
- Electron gets accelerated in diffusion region
- Acceleration dominated by non-ideal electric field
- Reconnection electric field acceleration



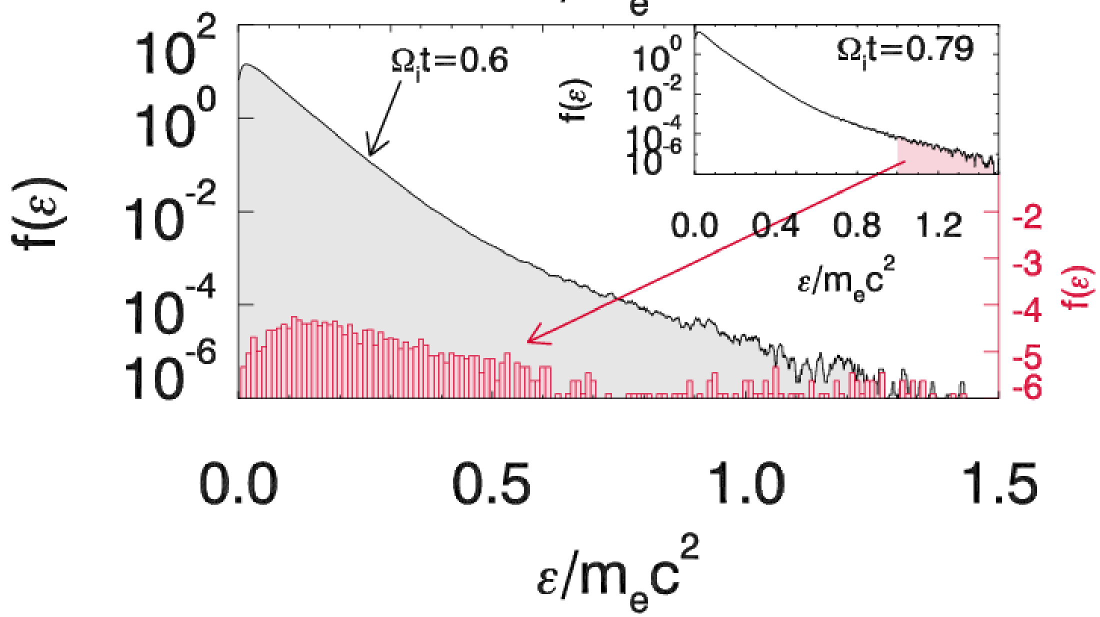
Simulation results

中国科学技术大学
University of Science and Technology of China

- ➢ Energy distribution of non-thermal electrons produced during squeezing stage at initial time ($\Omega_i t = 0$)
- Energy threshold



- ➢ Energy distribution of non-thermal electrons produced during reconnection stage at initial time ($\Omega_i t = 0.6$)
- No obvious multistep acceleration

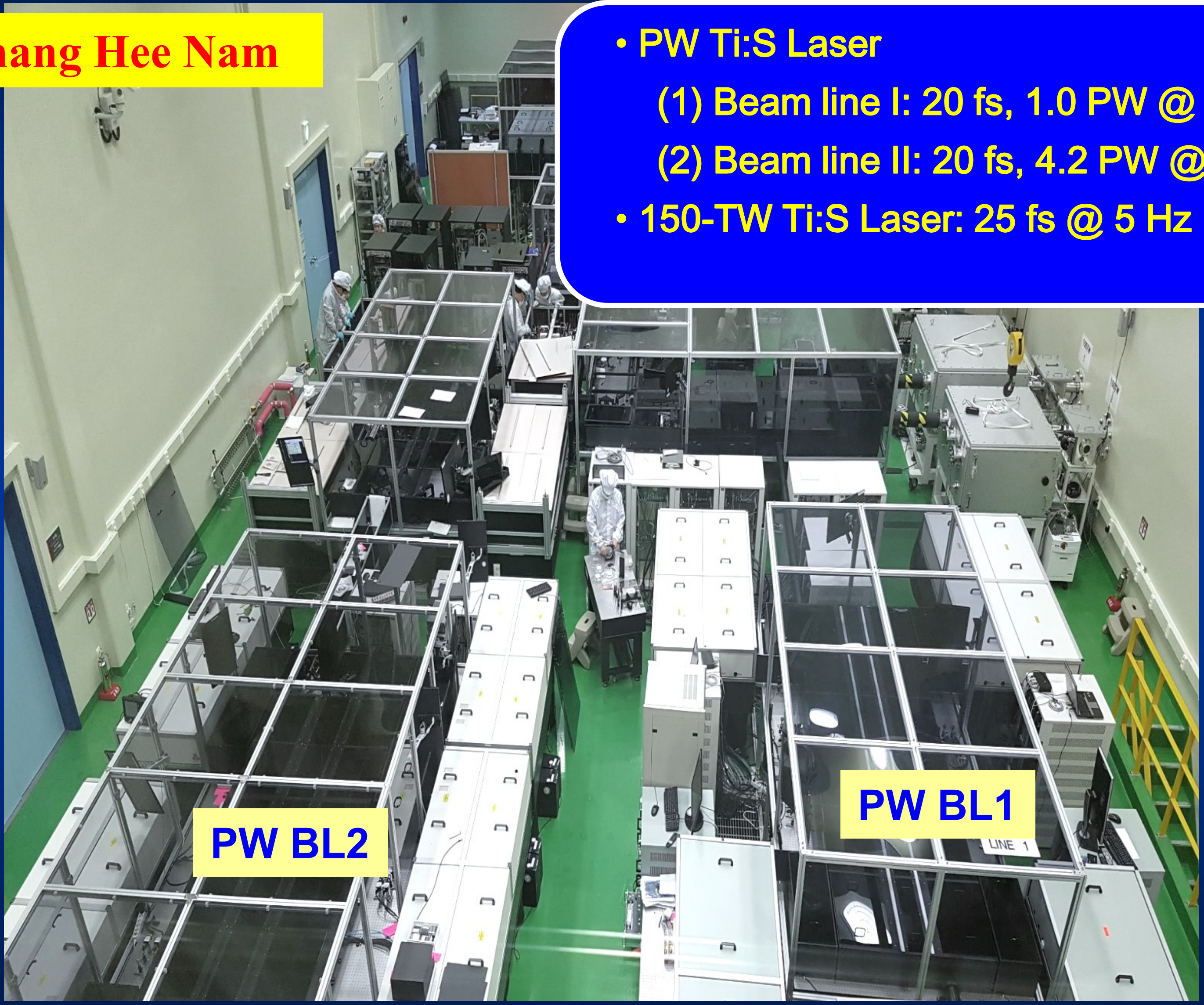


Ultra-high power laser system development
(multi-PW lasers, intensity contrast control)

IBS Center for Relativistic Laser Science

L-I14: Chang Hee Nam

- PW Ti:S Laser
  - (1) Beam line I: 20 fs, 1.0 PW @ 0.1 Hz
  - (2) Beam line II: 20 fs, 4.2 PW @ 0.1 Hz
- 150-TW Ti:S Laser: 25 fs @ 5 Hz



All Optical Compton Experiments

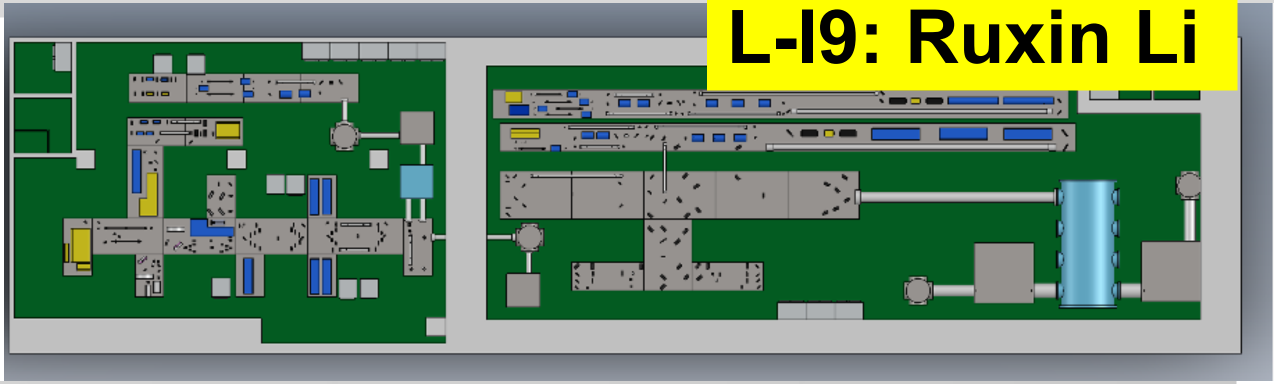
L-I14: Chang Hee Nam

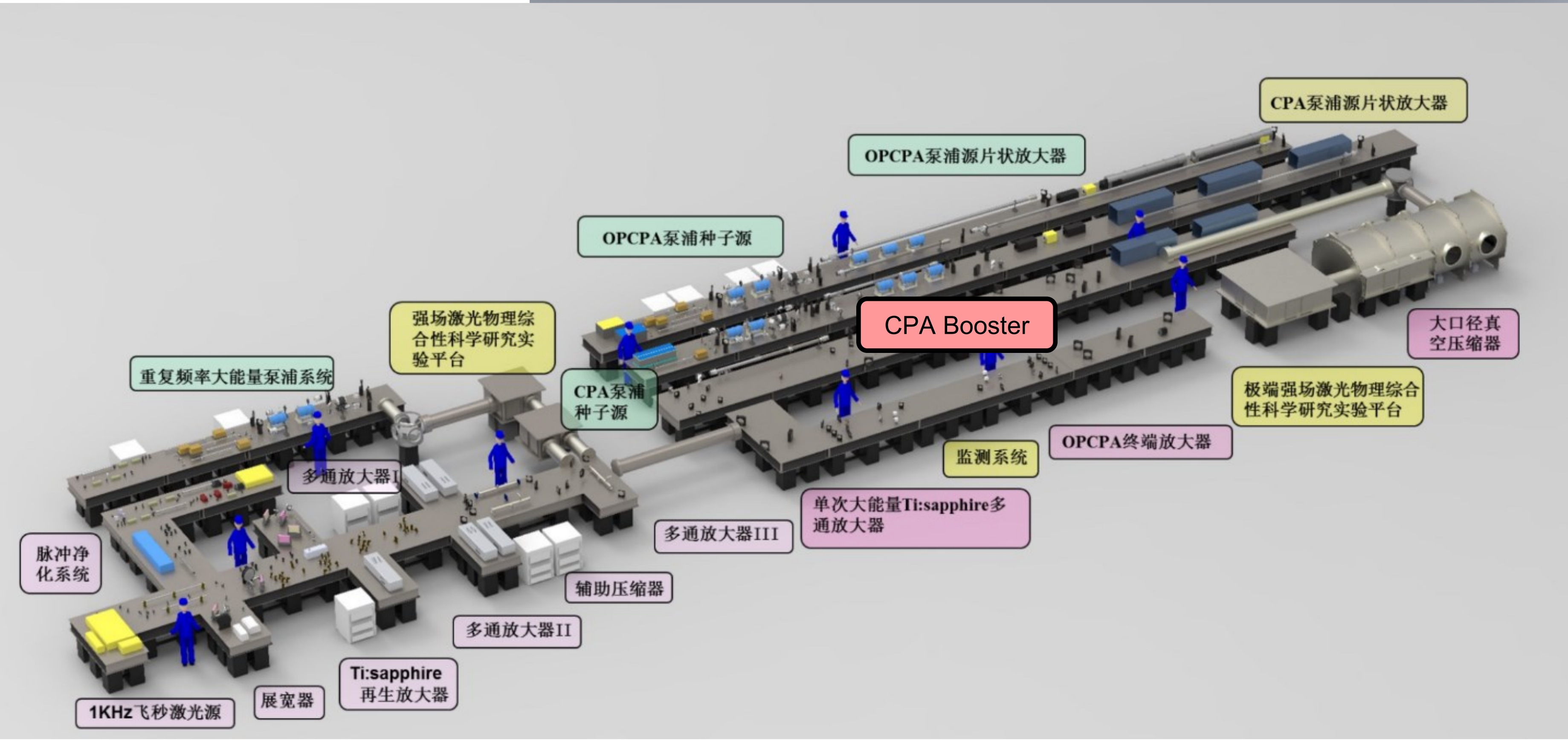
- **Laser Compton γ-ray production** via the interaction of **GeV e-beam** with **10^{18} - 10^{22} W/cm^2** laser field
  - **Compton backscattering**: $e^- + \omega_0 \rightarrow e^- + \gamma$
    MeV-Gamma beams useful for photo-nuclear physics
  - **Nonlinear Compton Scattering**: $e^- + n\omega_0 \rightarrow e^- + \gamma$
  - Measuring **radiation reaction** effects
    Energy loss and radiation damping (cooling) of electron beam
  - Breit-Wheeler pair creation: $\gamma + n\omega_0 \rightarrow e^- + e^+$
  - Assessing strong field QED theories

SULF implement the 10PW laser in a new lab. (2015-)

L-I9: Ruxin Li

SULF (Shanghai Superintense Ultrafast Laser Facility): 200J/20fs





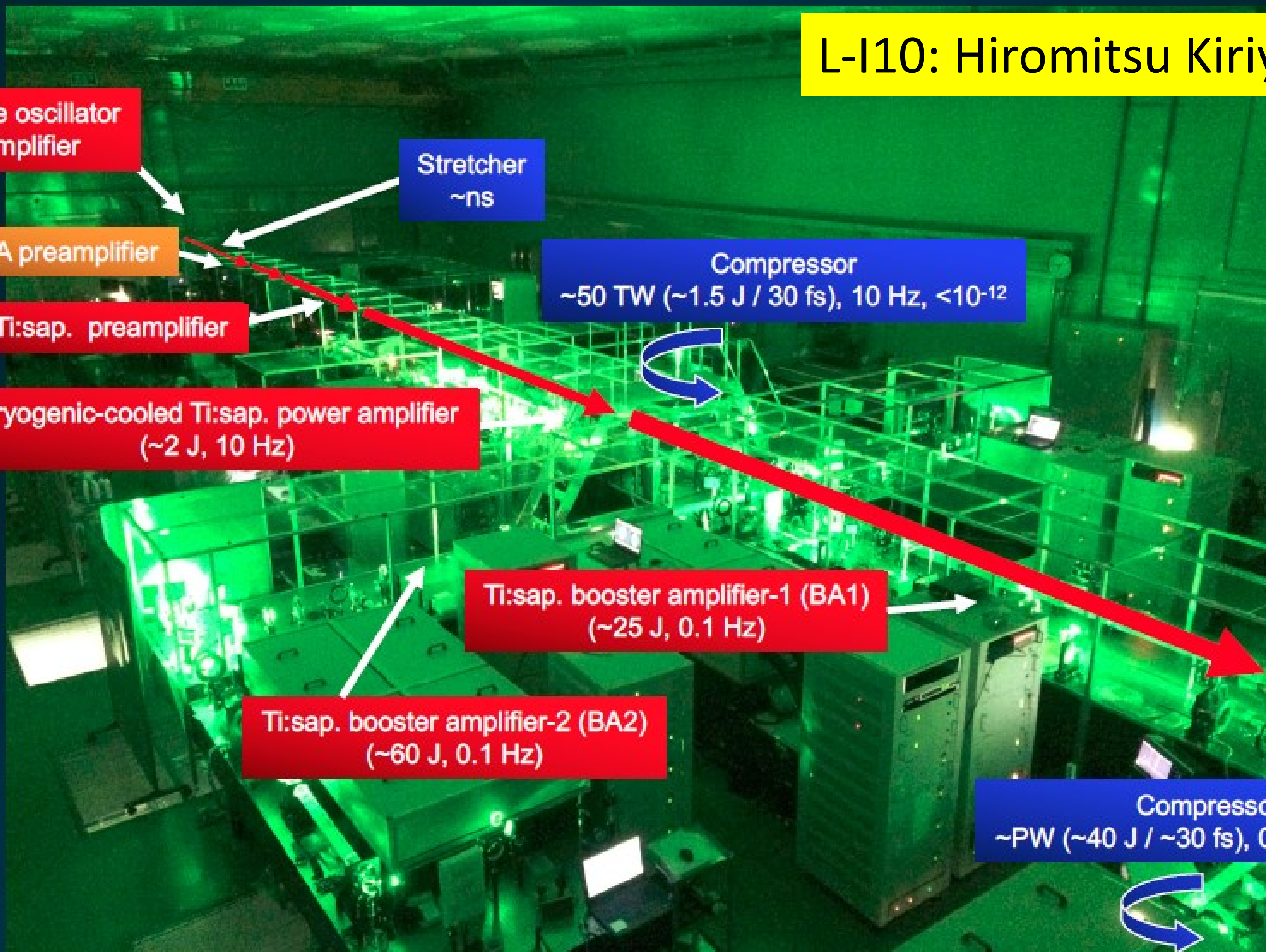
SULF

The layout as of 2016/08

L-I9: Ruxin Li

Current view of the J-KAREN-P laser system

L-I10: Hiromitsu Kiriyama

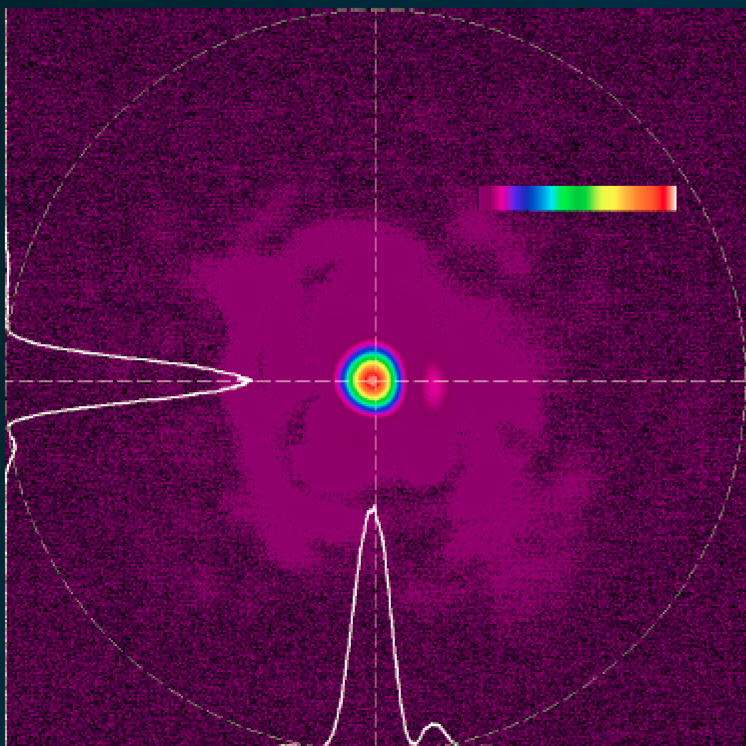


H. Kiriyama *et al.*, IEEE Sel. Topics J. Quantum Electron. (Invited paper), 21 (2015) 1601118.

Focal spot has been evaluated using an OAP with f/1.3 – approaching diffraction limit –

L-I10: Hiromitsu Kiriyama

✓ Focal spot



10^{22} W/cm^2 at 0.1 Hz is achieved at 0.3 PW power level

✓ Parameters

Parameter	2016-11-08 Ti:S BA1	Diffr. Limit
FWHM x, μm	1.32±0.05 (4%)	1.07
FWHM y, μm	1.37±0.03 (2%)	1.23
FW1/e^2 x, μm	2.19±0.15 (7%)	1.72
FW1/e^2 y, μm	2.30±0.17 (8%)	2.04
Energy above 1/2, %	32±4 (11%)	50
Energy above 1/e^2, %	56±2 (4%)	82
I_0 at 300 TW, W/cm^2 (f/1.25)	(0.93±0.12)×10^{22}	2.0×10^{22}
Strehl ratio	0.46±0.06	1

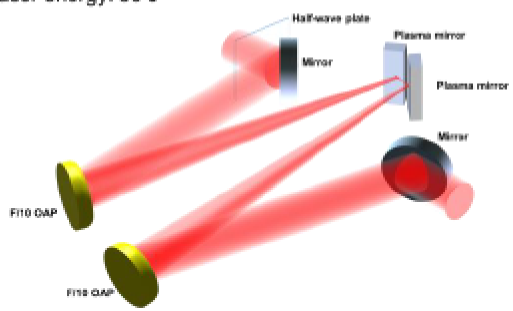
A. S. Pirozhkov *et al.*, Opt. Exp., 25 (2017) 20486.

Double Plasma Mirror System

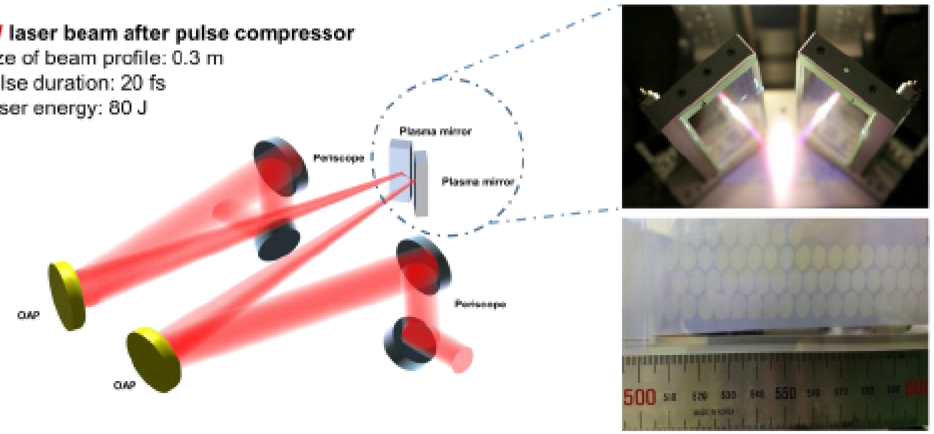
Seong G. Lee

Experimental Setup

1 PW laser beam after pulse compressor
- Size of beam profile: 0.2 m
- Pulse duration: 30 fs
- Laser energy: 30 J



4 PW laser beam after pulse compressor
- Size of beam profile: 0.3 m
- Pulse duration: 20 fs
- Laser energy: 80 J



Recently, advanced type of double plasma mirror system was established in CoReLS, Korea.

For 4 PW laser system, Reflectivity of the double plasma mirror is measured ~70% which shows better performance compare to the reflectivity measured with 1 PW laser system by ~40%.

When plasma mirror transform from transmissive surface to reflective surface within 5ps, it has higher reflectivity than the case after 5ps.

Laser plasma based particle acceleration and radiation

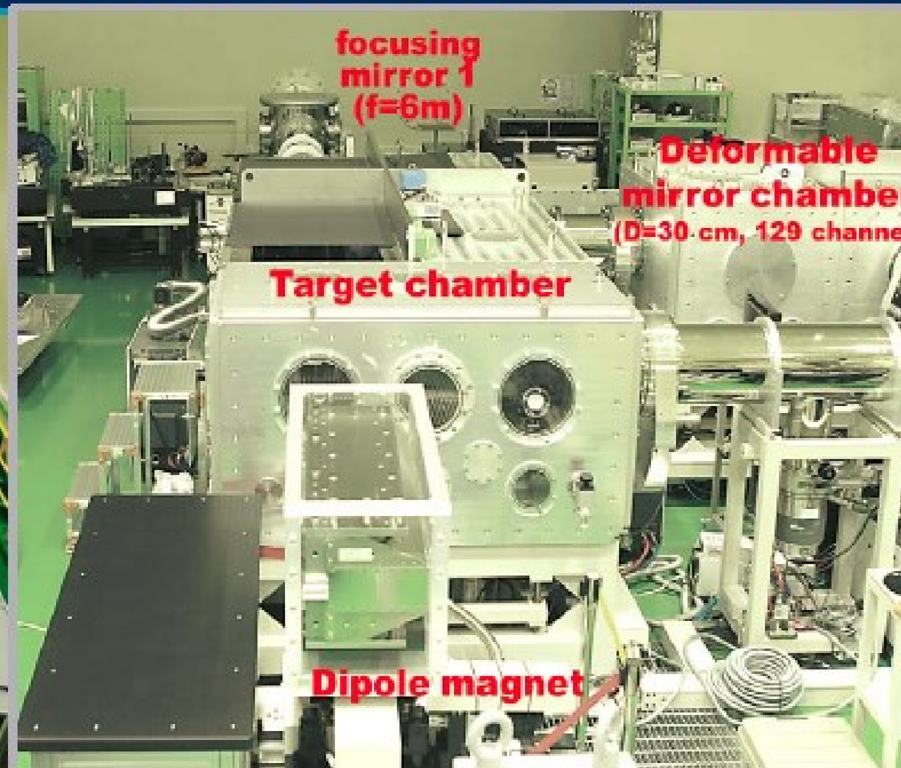
(electron acceleration: higher energy, higher quality, higher acceleration gradients)

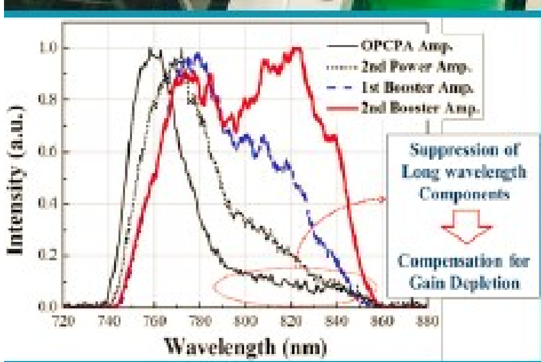
P7 H.T. Kim

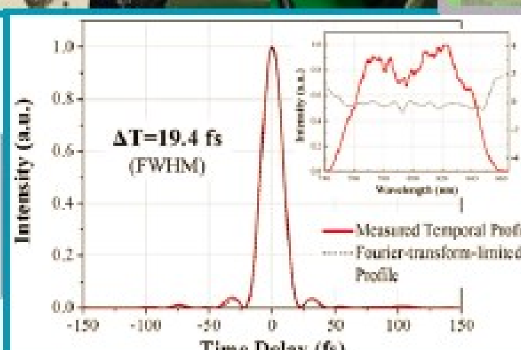
4 PW Laser & LWFA setup at CoReLS

4 PW + 1 PW Laser

Electron acceleration chamber



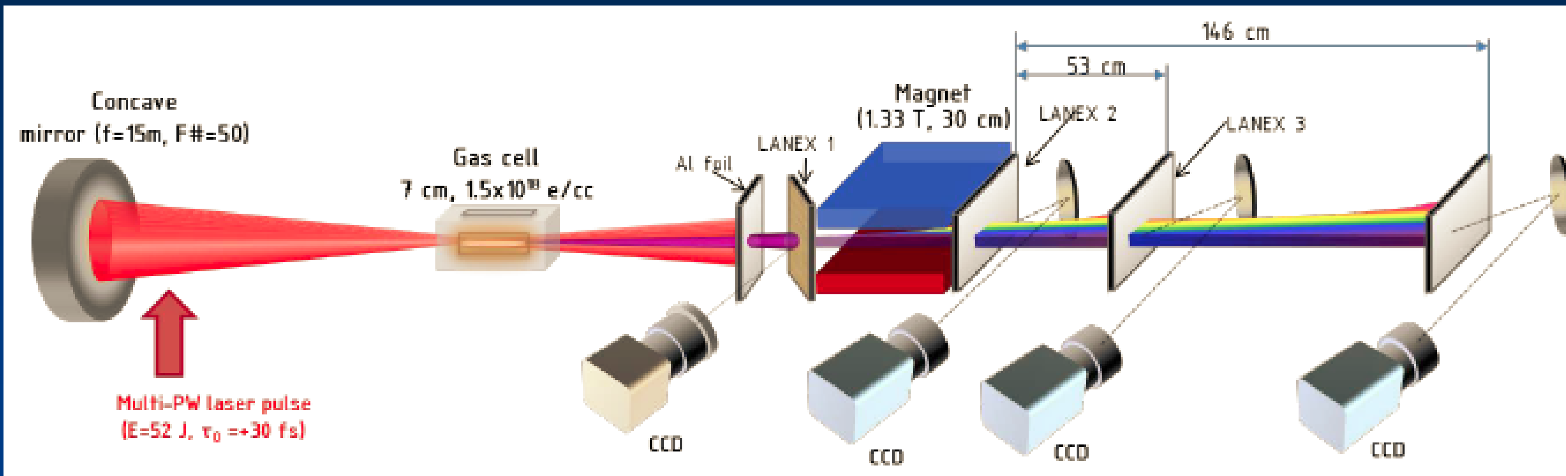




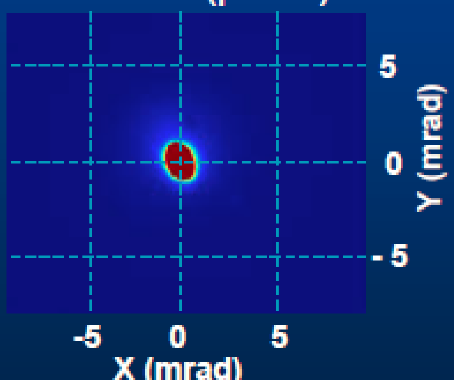
P7 H.T. Kim

Preliminary results using multi PW laser pulses

Laser parameters : 52 J on target, focal spot ≈ 50 μm (FWHM), + 30 fs (GDD +350 fs^{-2}), I ≈ 4 x 10^{19} W/cm^2, a_0 ≈ 4.5
Gas medium : He mixed with 1-% Ne, 7-cm gas cell, plasma density ≈ 1.5 x 10^{18} elec./cc



LANEX 1 (profile)



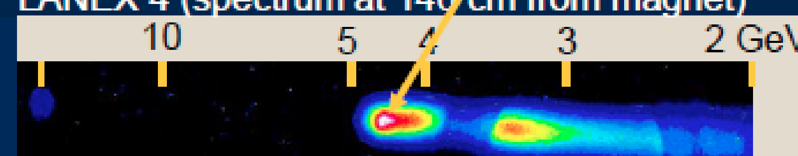
Deeply saturated
Divergence < 2 mrad
Total Charge >> 1 nC

LANEX 2 (spectrum at the end of magnet)

Electron energy at peak
≈ 4.5 GeV

LANEX 3 (spectrum at 53 cm from magnet)

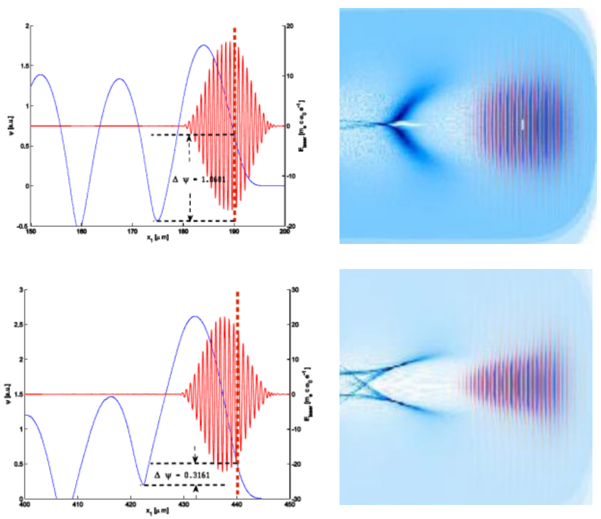
LANEX 4 (spectrum at 146 cm from magnet)



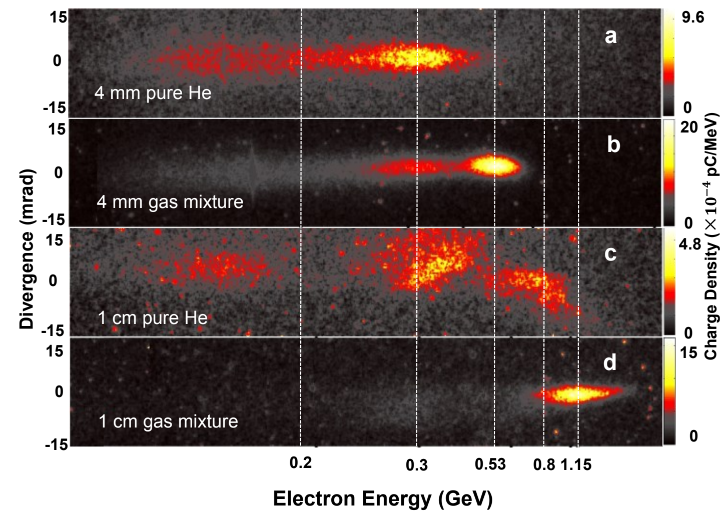
High quality electron acceleration in LWFA based on controlled ionization injection

L-I18 Min Chen

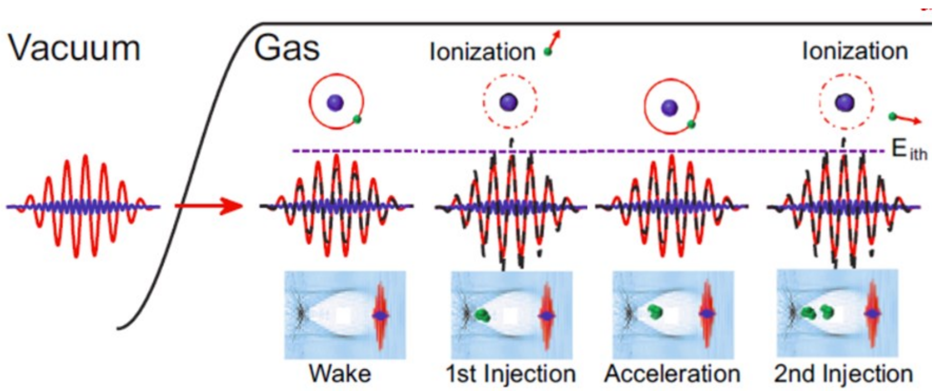
1. Self-truncated ionization injection



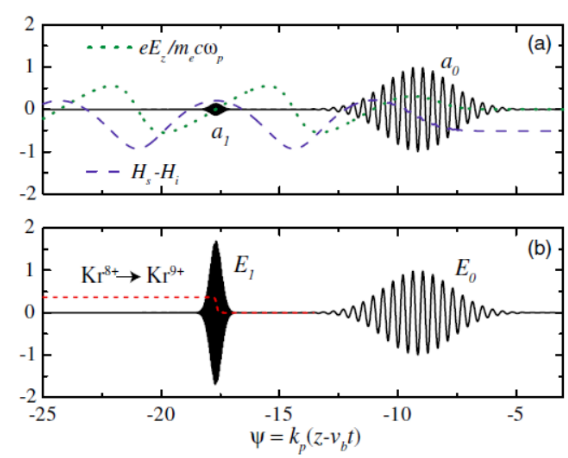
2. STII demonstration at SJTU



3. Two color ionization injection low energy spread



4. Two color ionization injection low transverse emittance



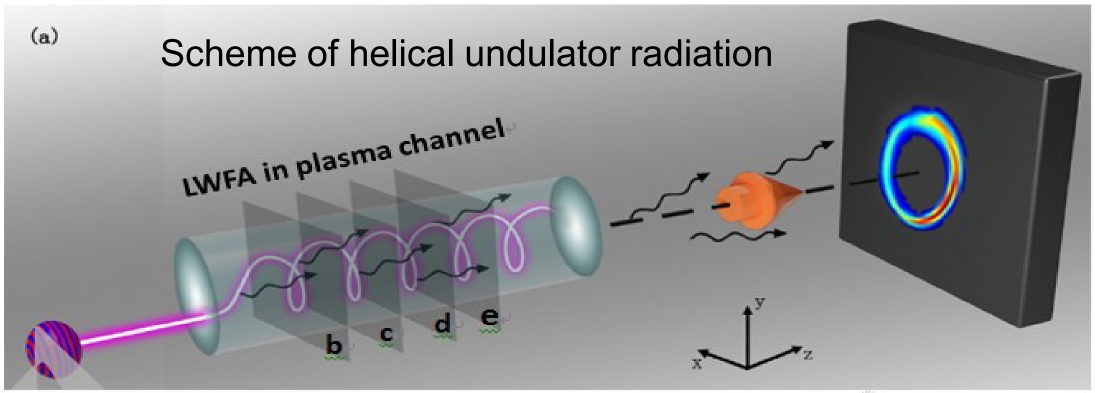
激光等离子体教育部重点实验室

Key Laboratory for Laser Plasmas，SJTU

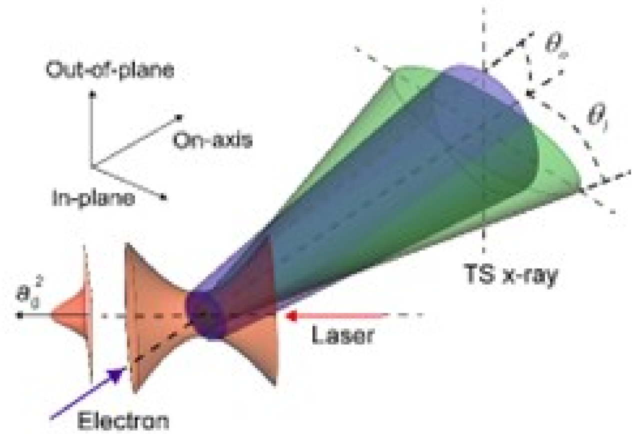
Plasma undulator and Nonlinear Thomson scattering

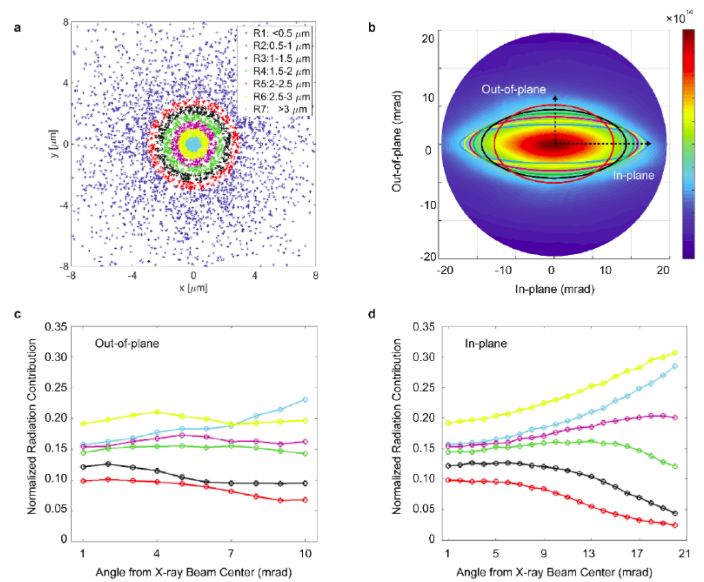
L-I18 Min Chen

1. Plasma channel based undulator radiation



2. Nonlinear Thomson scattering





References:

[1] L.L. Yu et al., Phys. Rev. Lett. 112, 125001 (2014)

[1] M. Zeng et al., Phys. Rev. Lett. 114, 084801 (2015)

[2] M. Mirzaie et al., Sci. Rep. 5, 14659 (2015)

[3] M. Chen et al., Light： Science & Applications. 5, e16015. (2016)

[4] J. Luo, et al, Sci. Rep. 6, 29101 (2016)

[5] W.C. Yan, et al., Nat. Photonics,11,514 (2017)

激光等离子体教育部重点实验室

Key Laboratory for Laser Plasmas , SJTU

L-I 8: Jianfei Hua

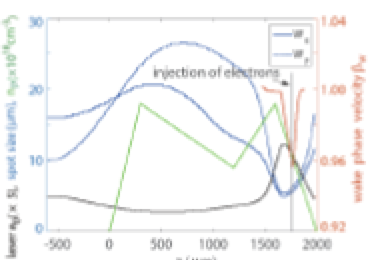
A high quality laser wakefield injector with sub-half MeV absolute energy spread at Tsinghua Univ.

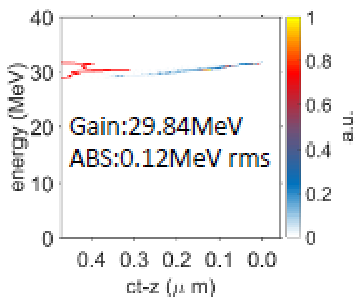
Very low absolute energy spread (AES) and relative energy spread (RES) observed using 5TW 60fs laser system:

On many shots, AES below 0.5MeV (rms), with the lowest 0.18MeV

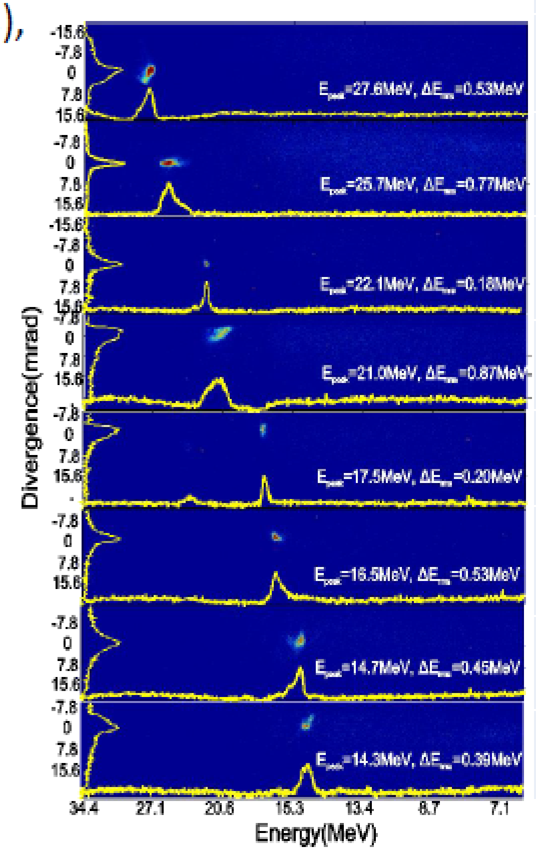
On many shots, RES around 1-2% (rms), with the lowest 0.8%

Small divergence of a few mrad, with the smallest 1.2mrad



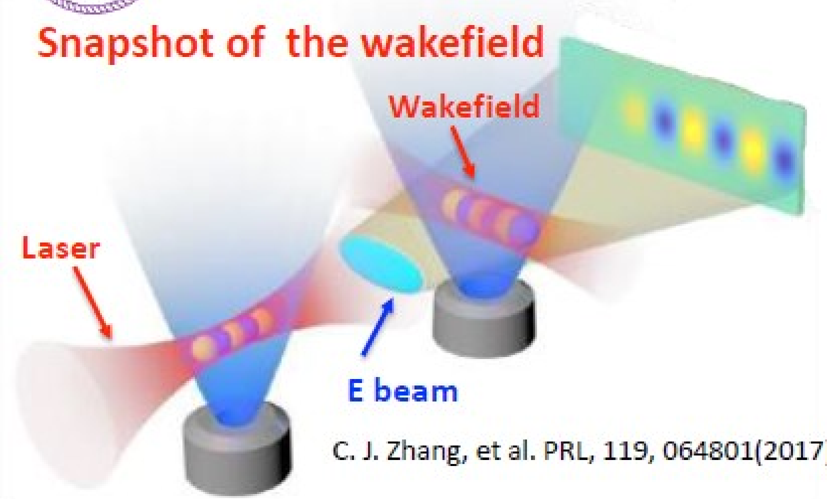


Booster in second accelerator:
Energy gain:1.9GeV;
ABS: 0.365MeV rms; RES:0.0192% rms



Energy (MeV)	Absolute energy spread(rms) (MEV)
27.6	0.53
25.7	0.77
22.1	0.18
21.0	0.87
17.5	0.20
16.5	0.53
14.7	0.45
14.3	0.39

Femtosecond Relativistic Electron Probe

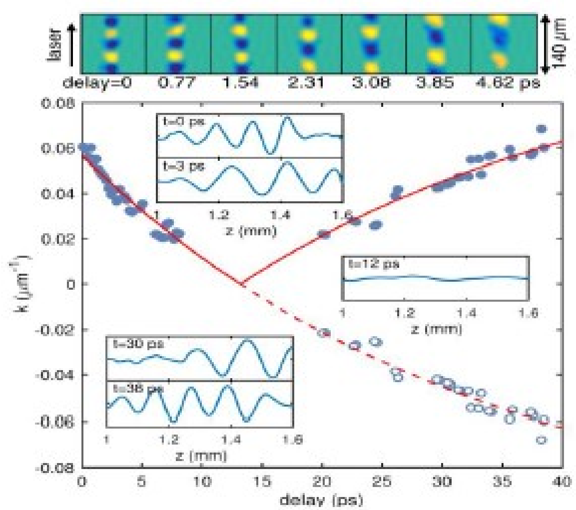


C. J. Zhang, et al. PRL, 119, 064801(2017)

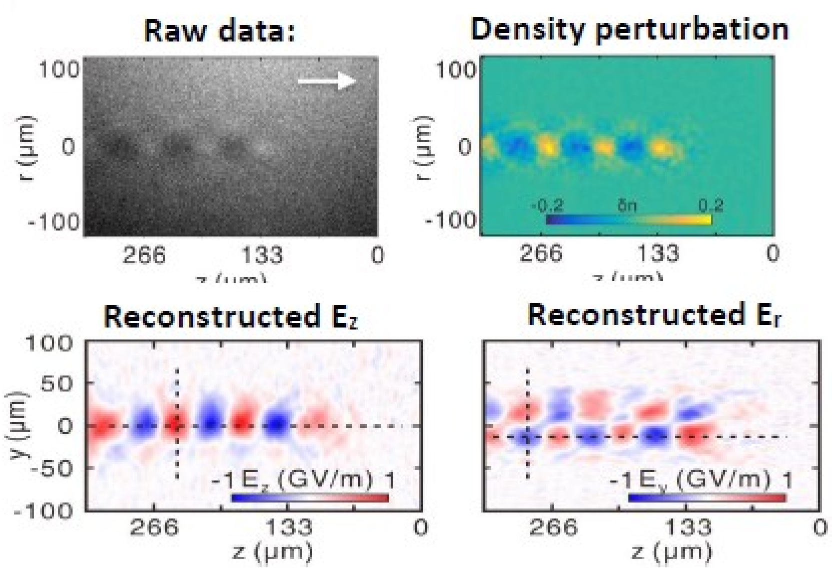
Benefits:

- ✓ Direct measurement of field;
- ✓ Work at Low density plasma.

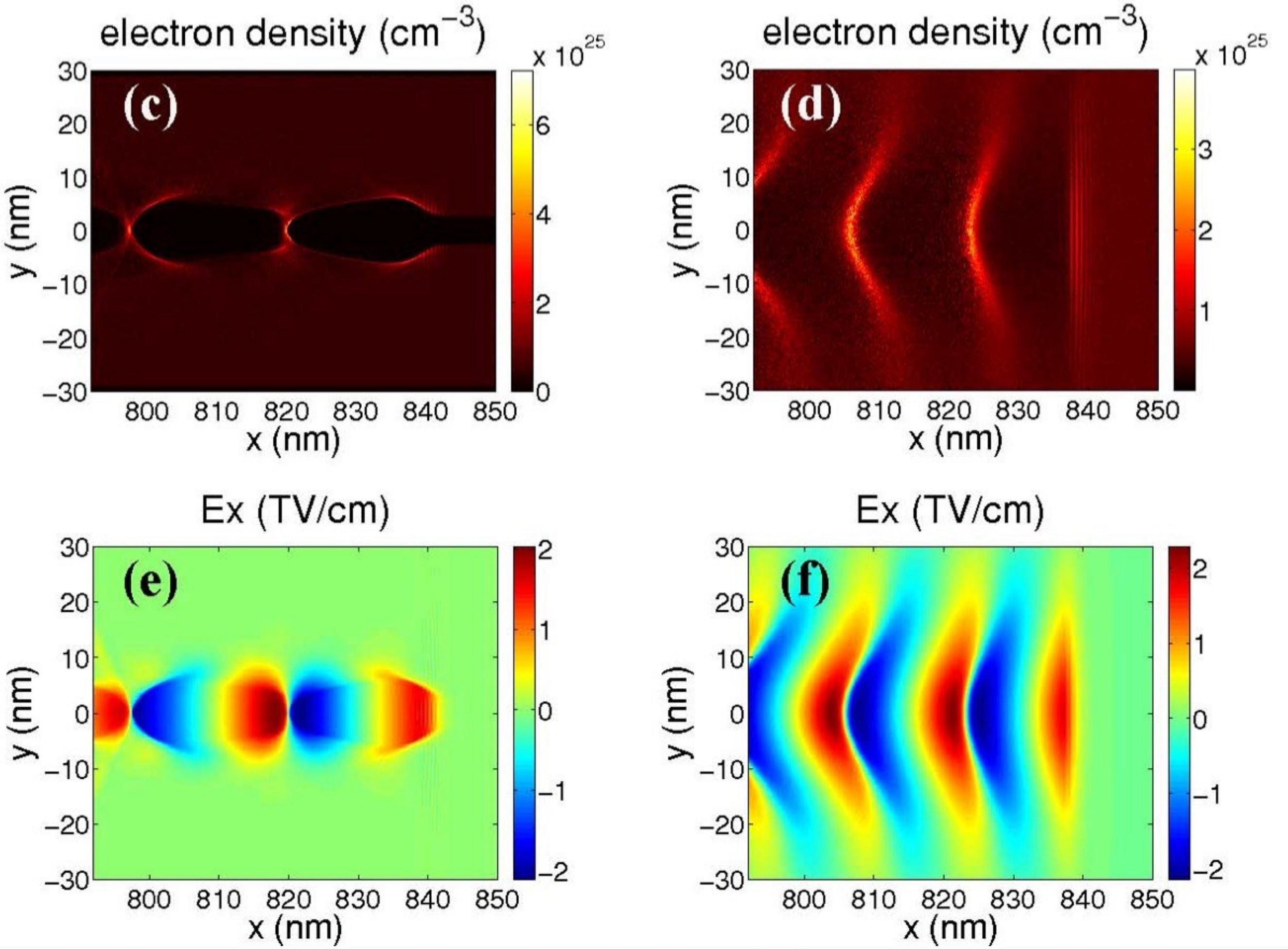
- ✓ E_z field: Sin form
- ✓ E_r field: $r*\exp(-r^2/\sigma^2)$
- ✓ Peak Ez is ~1 GeV/m
- ✓ Linear Er field (+/-8μm)



Observation of the Plasma Wake Reversal



Guided versus unguided

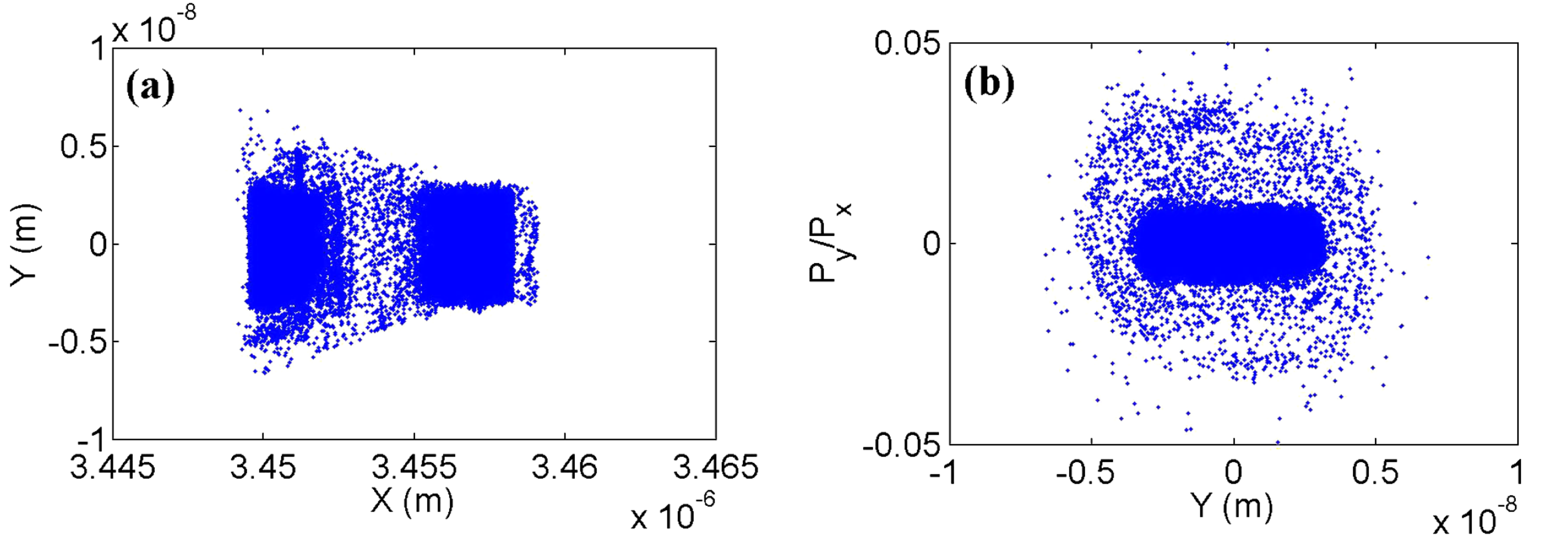


For 1 nm drivers, energy gain is 2TeV/cm

Energy gain gradient is 2TeV/cm instead of 2GeV/cm in the optical laser case.

X ray laser can be well guided by nanotube

Emittance



(a) The space distribution (x, y) and (b) the transverse phase space (y, p_y/p_x) of the top 80% highest energy electrons in the case of X-ray laser.

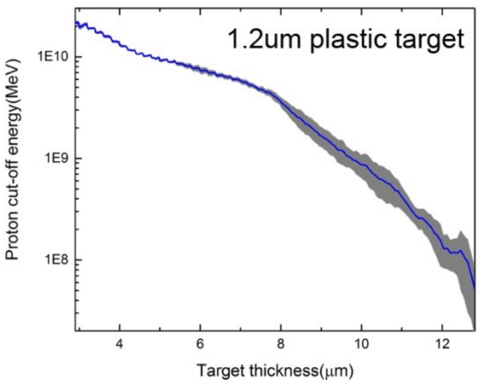
Electron transverse motion is drastically reduced but momenta is the same, so emittance is expected to be reduced.

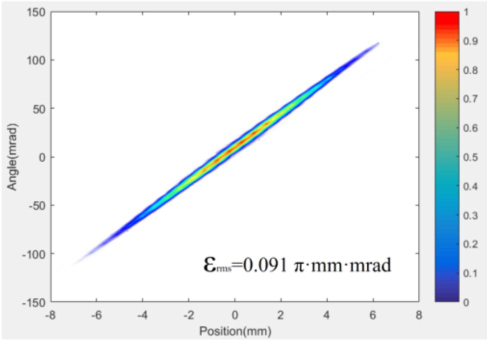
Top 80% energetic particles

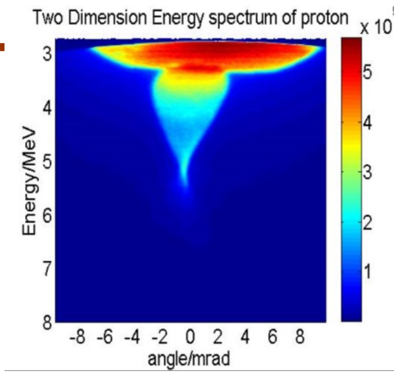
Laser plasma based particle acceleration and radiation

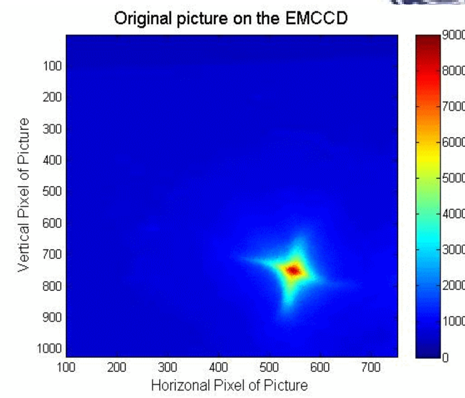
(Ion acceleration: new facility, new target designs for better control, multiple beam effects, neutron atom acceleration)

1. Compact LAser Plasma Accelerator is running @PKU









1) Small emittance &&

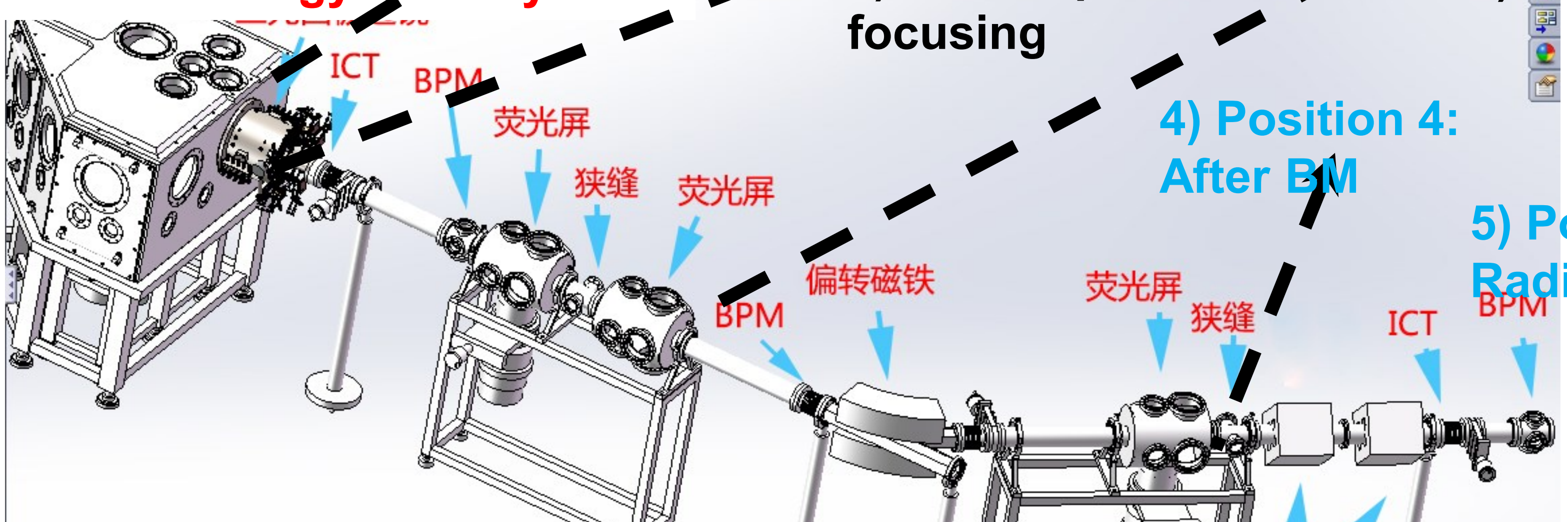
Proton energy stability <3%

2) Quadrupole focusing

3) Before Analyzing

4) Position 4: After BM

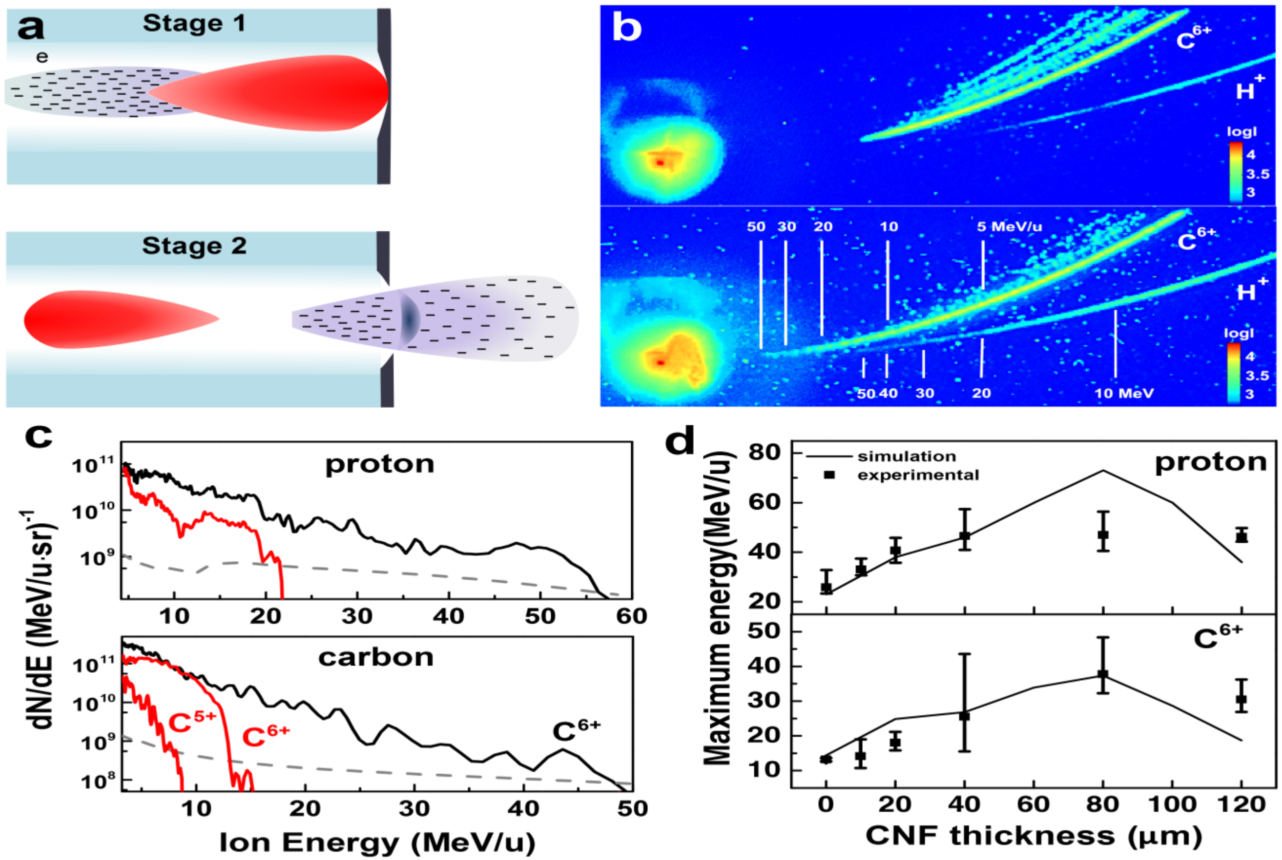
5) Position 5: Radiation Platform



L-I13: X. Yan

2. 0.6 GeV Carbon acceleration in cascaded acceleration RPA+TNSA

Carbon Nano-Tube + DLC foil **W.J.Ma, Kim…X.Q.Yan, C.H.Nam, submitted 2017**

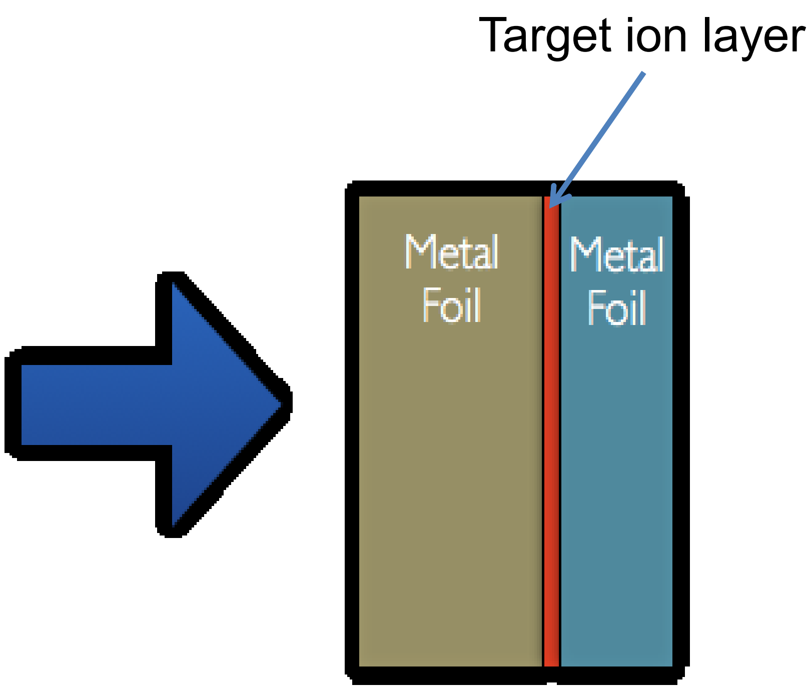


~4 times enhancement, compared to one stage RPA acceleration

Experiments were performed using CoReLS PW Laser in Korea (Prof. C. H. Nam), cooperation between GIST and PKU

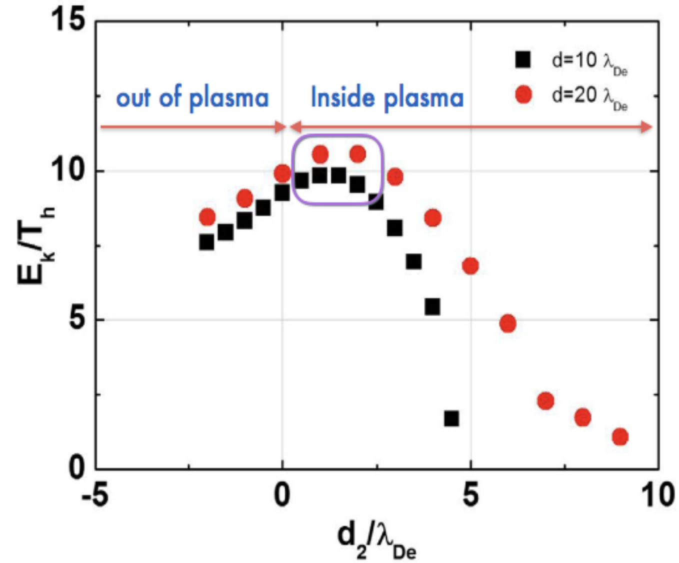
Layered Target

- For the generation of an energetic proton beam with narrow energy spread
- By utilizing a Bulk electrostatic field in the plasma

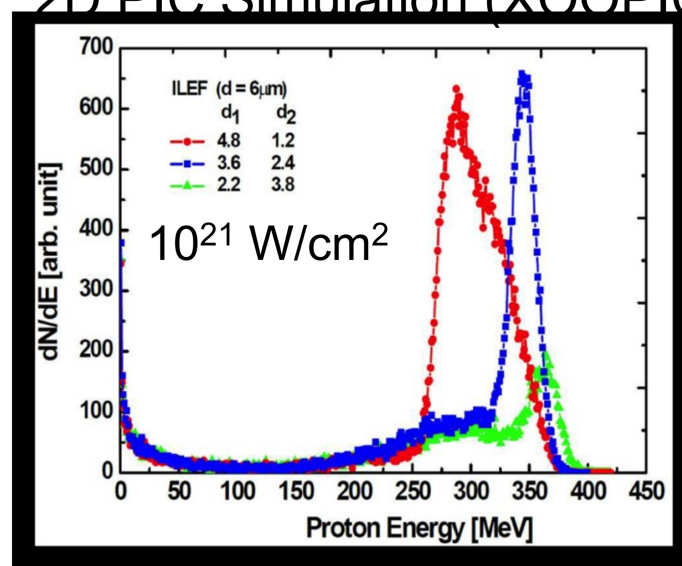


Ion Layer-Embedded Foil target

1D Fluid Simulation



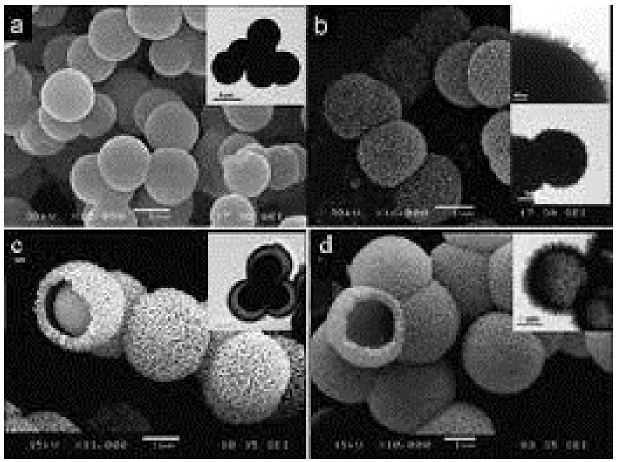
2D PIC Simulation (XOOPIC)



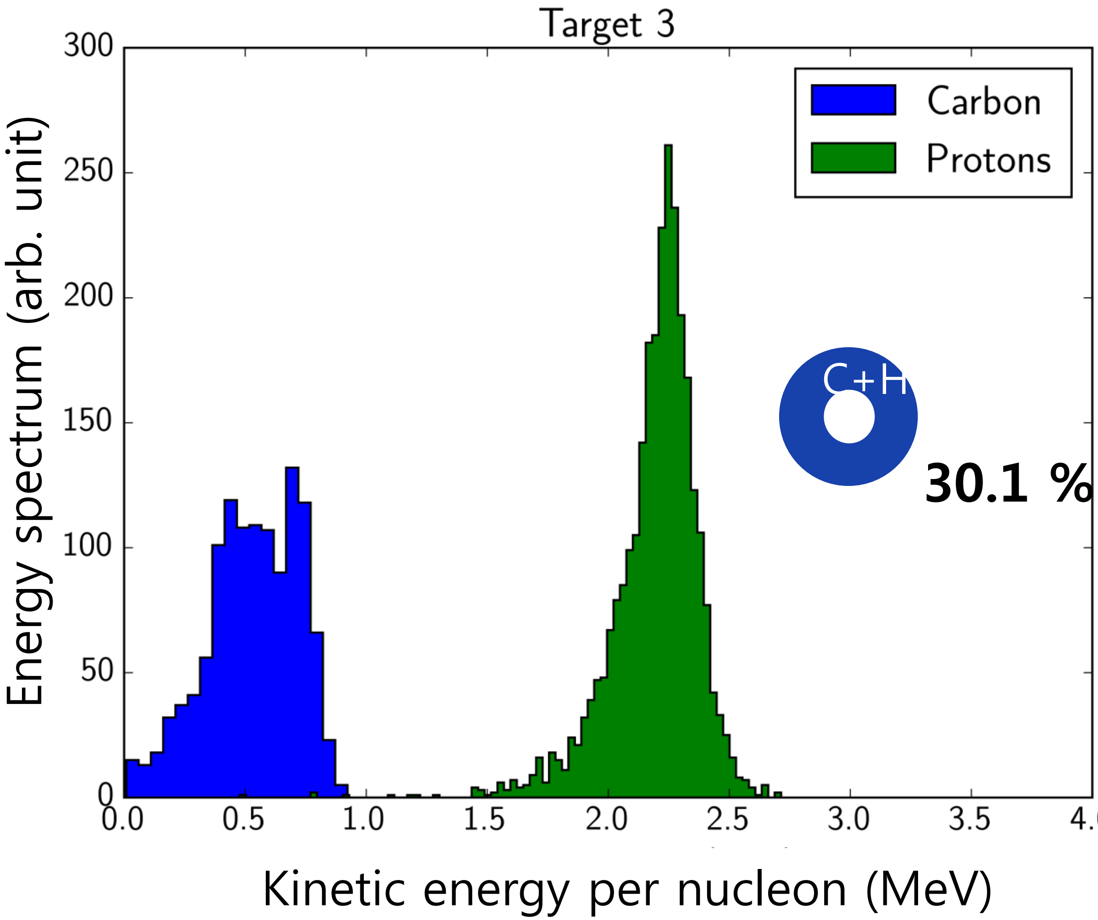
L-I15: Kitae Lee

Compact and efficient laser-neutron source

3D MD simulation shows that very high conversion efficiency ~ 30% can be obtained by hollow nanosphere



Hollow cluster targets

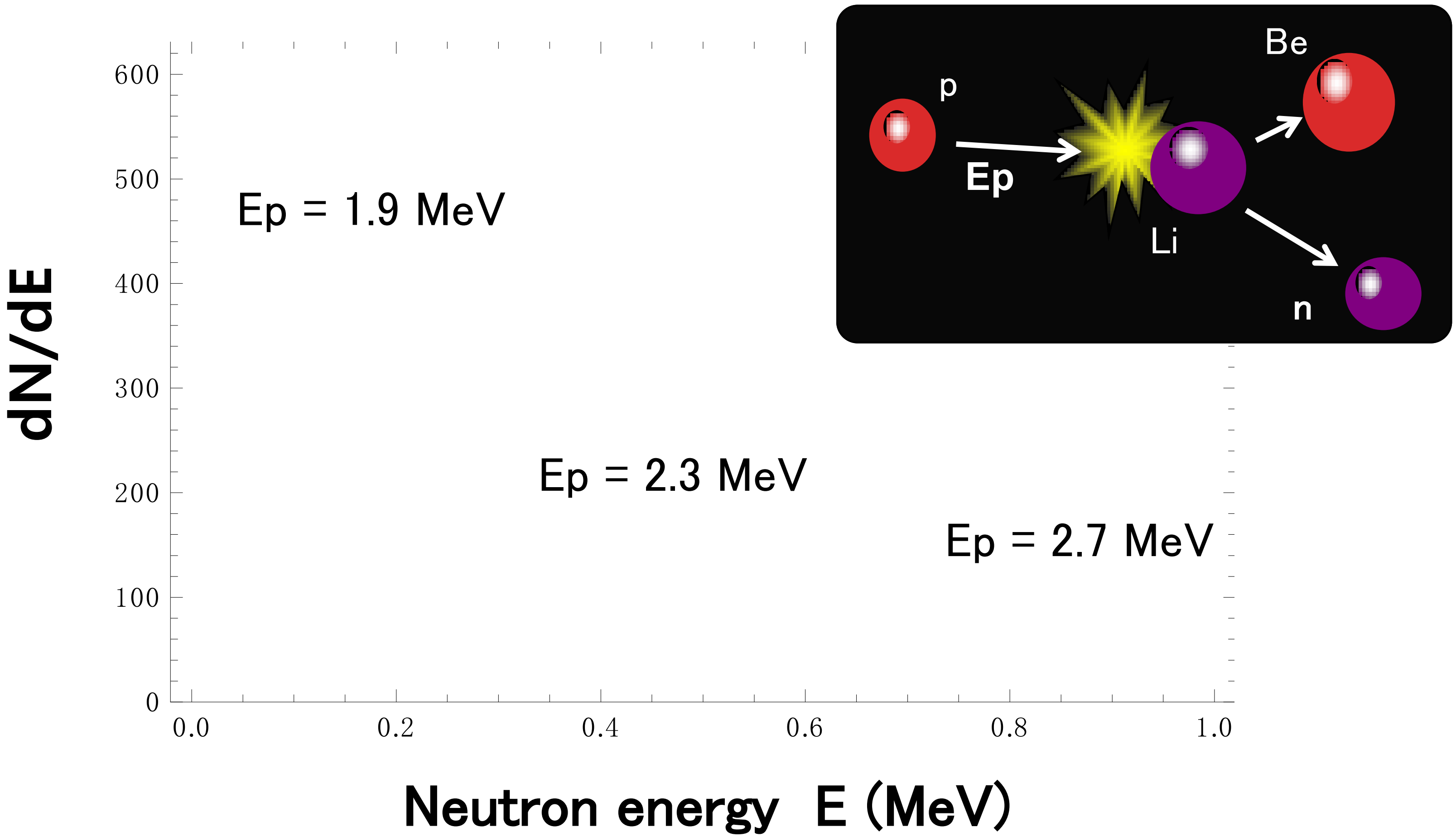


L-I26: M. Murakami

Neutron energies produced by pLi –reaction are dramatically reduced due to the endothermic reaction

Expected moderator thickness for low temperature neutrons is of the order of a few cm or even less.

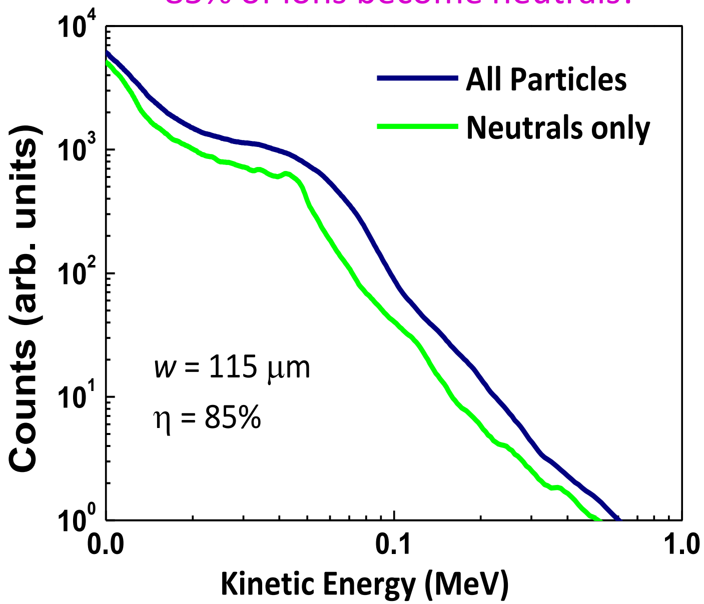
P + Li →n + Be −1.64 MeV



L-I26: M. Murakami

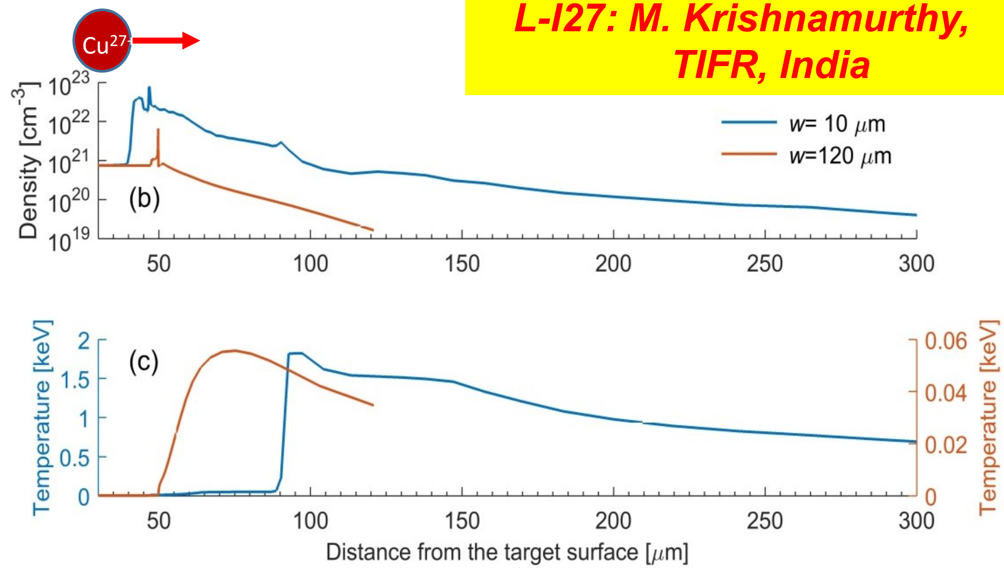
Accelerated atoms in laser produced plasmas

85% of ions become neutrals!

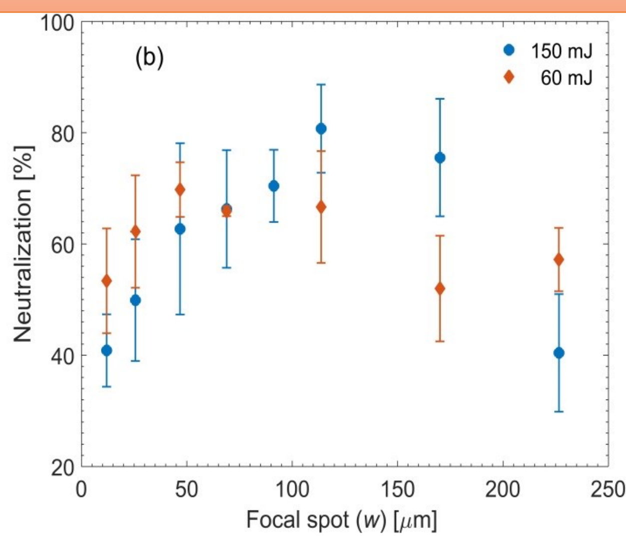


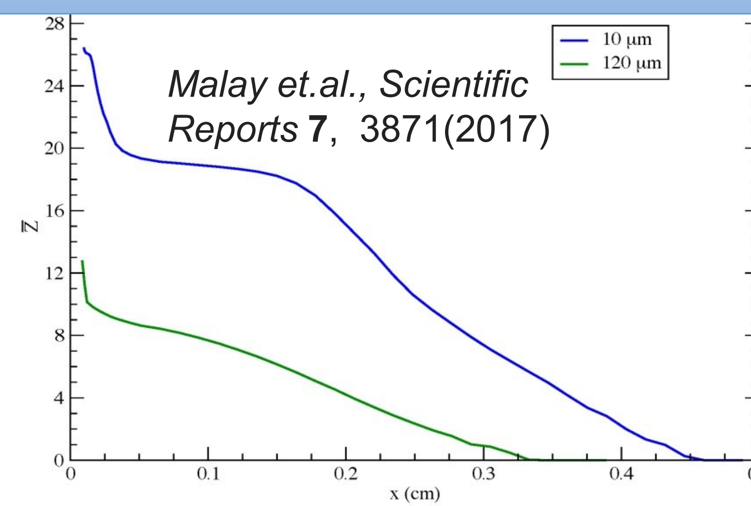
Neutral Cu atoms upto 1 MeV are generated

L-I27: M. Krishnamurthy, TIFR, India



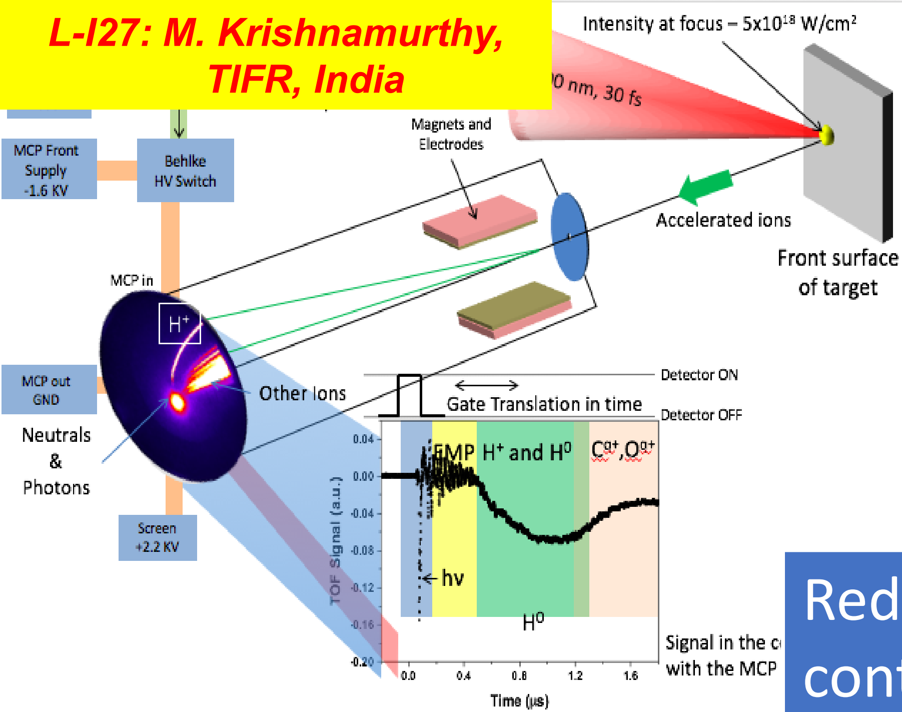
Ions passing through colder preplasma are efficiently neutralised





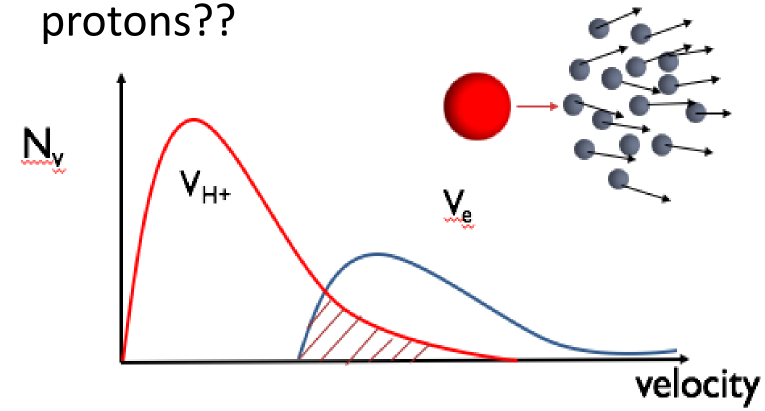
Focal waist size crucially controls the extent of neutralisaition

L-I27: M. Krishnamurthy, TIFR, India



Proposition:

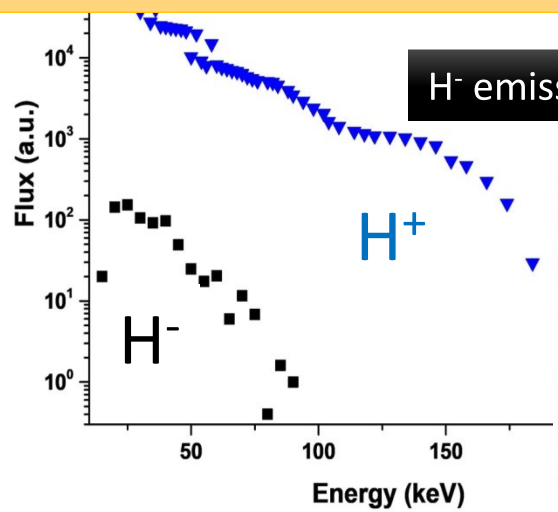
Co-propogation of electrons with protons??

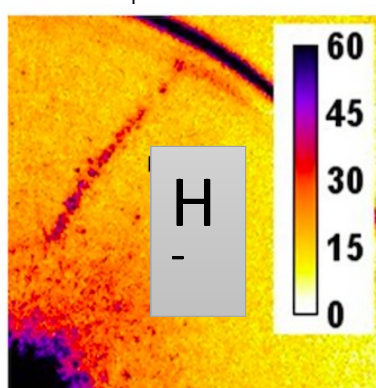


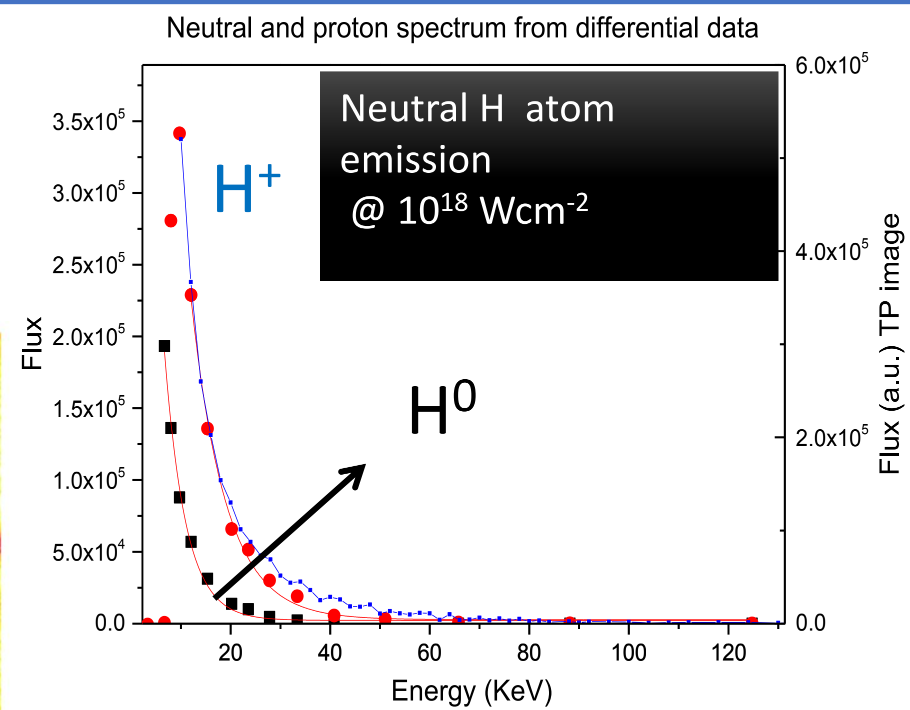
Reduced velocity in the proton frame can contribute to electron ion recombination.

Gated Thmospon spectrometer show H0 and H- emission from solid targets even at $10^{18} Wcm^{-2}$ high contrast pulses

H⁻ emission @ 10^{18} Wcm^{-2}





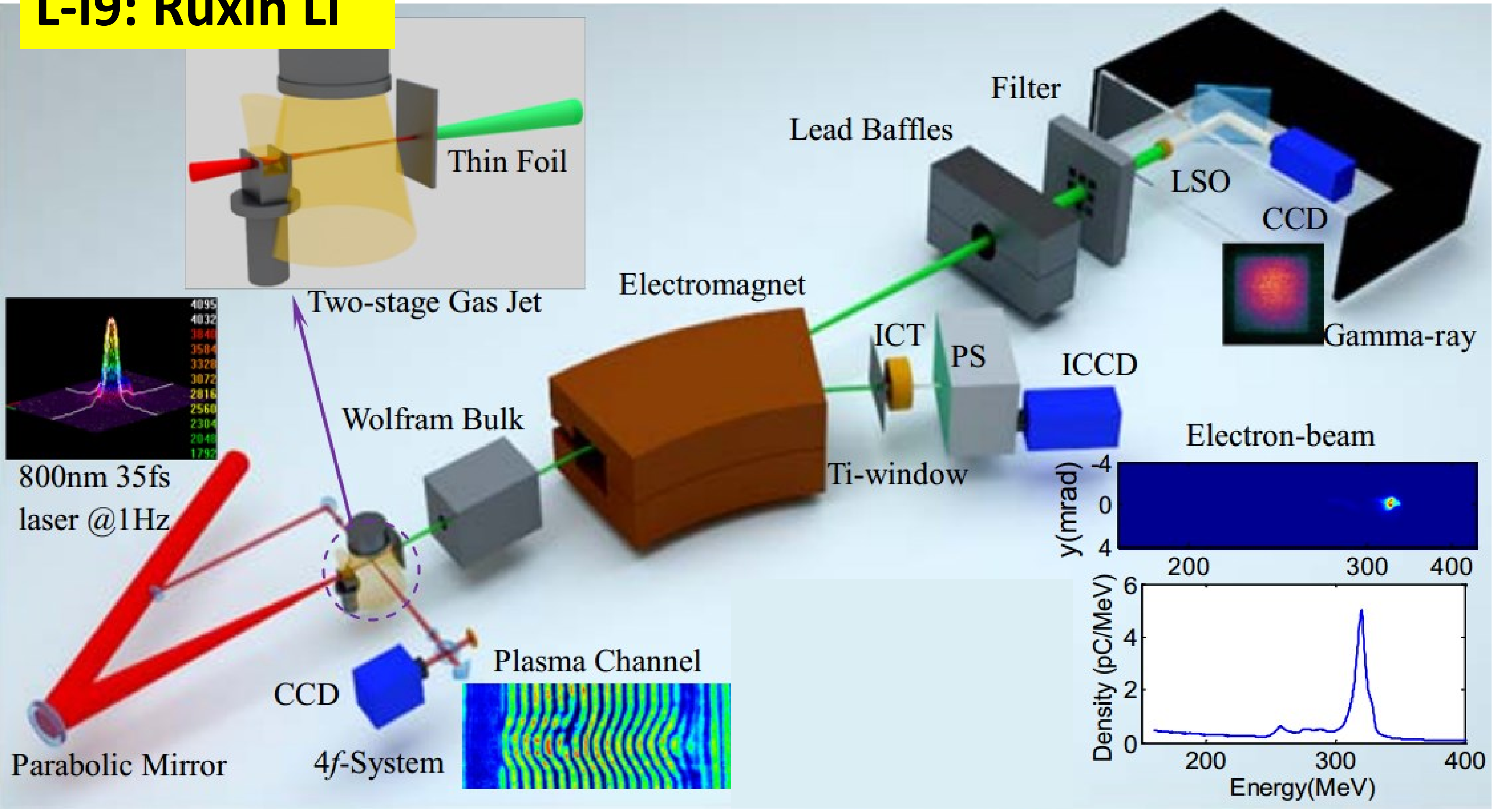


Laser plasma based particle acceleration and radiation

(Radiation: Compton scattering sources, gamma-rays near QED regime, mid-infrared radiation, etc.)

Compton scattering γ-rays based on high quality e beams

L-I9: Ruxin Li



Previous works: Ta Phuoc et al., Nat. Photonics 6, 308 (2012)

Tsai et al., Physics of Plasmas 22, 023106 (2015)

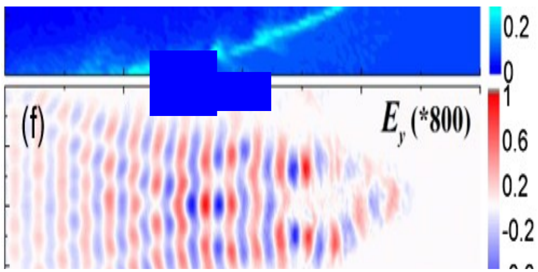
This work: C. Yu et al., Scientific Reports, 6, 29518 (2016)]

Self-matching resonant acceleration by CP laser is much more advantageous over direct laser acceleration by LP laser

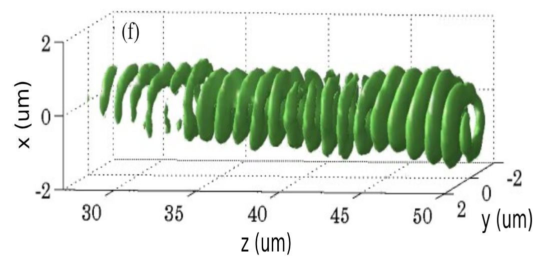
L-I 30-B. Qiao

Electron acceleration:

DLA under LP



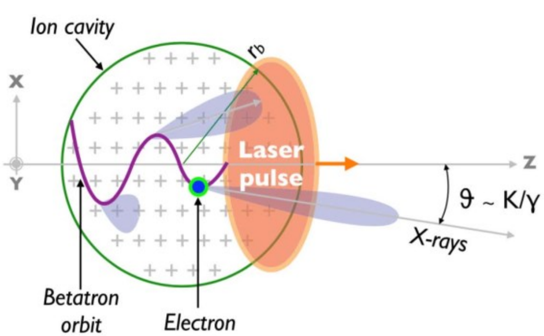
RA under CP



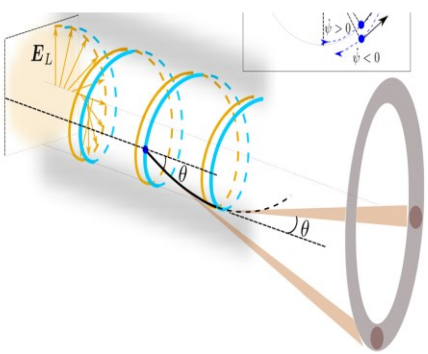
- Trapping can be enhanced by B_{sz}
- Self-matching process leads to that much more electrons can be preaccelerated to achieve resonant condition
- B_{sz} contributes to the betatron frequency, help to reach the resonance condition

Synchrotron radiation:

DLA under LP



RA under CP

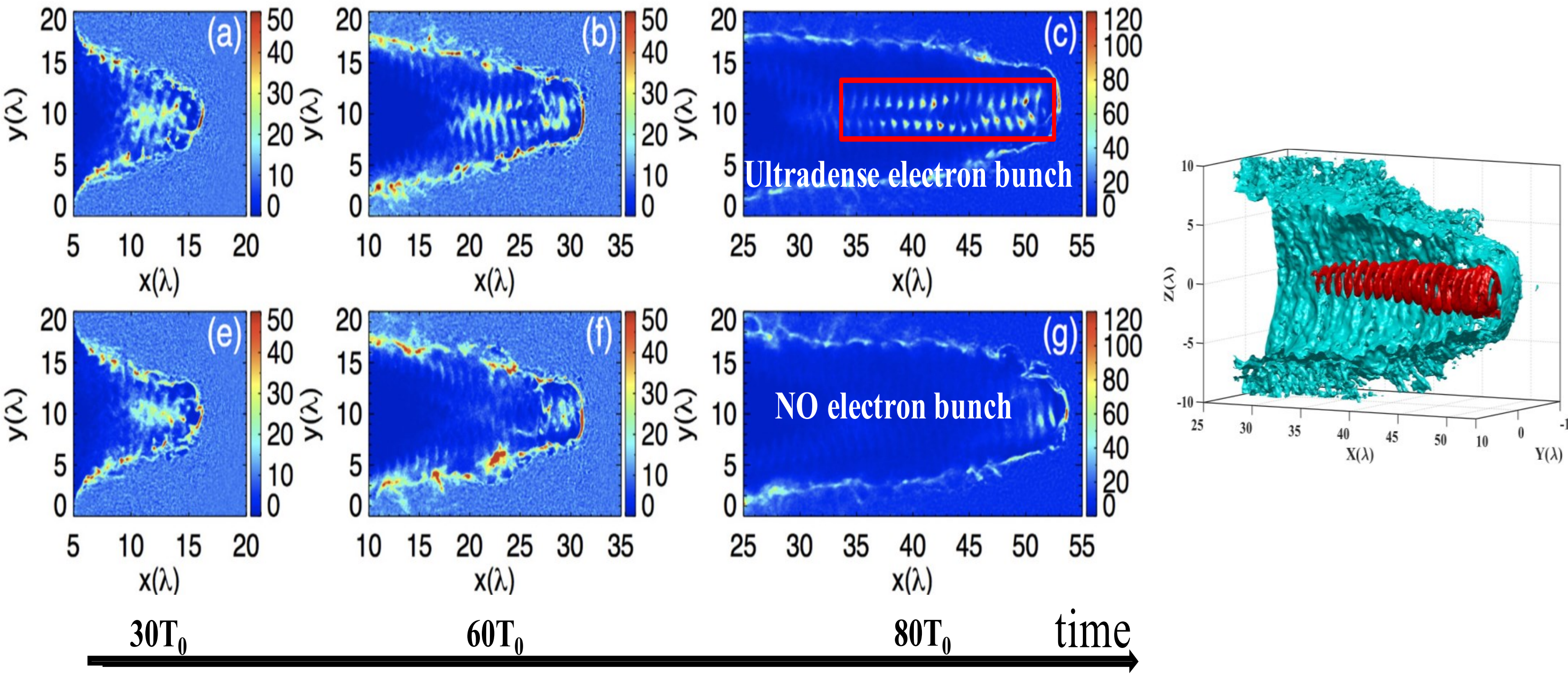


- Synchrotron radiation can be much enhanced due to helical motion trajectory (always locate at the "turning" point)
- γ-ray photon radiation has vortex structure

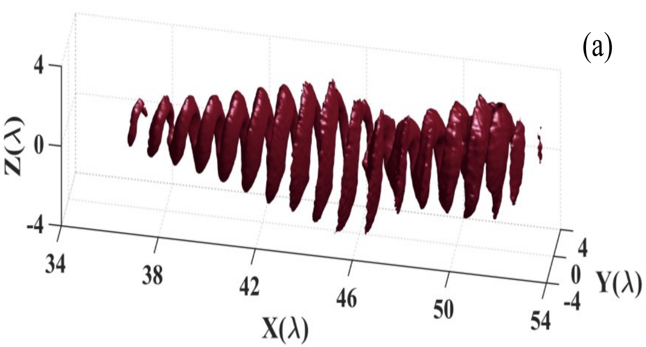
A new resonance acceleration scheme for generating ultradense relativistic electron bunches and emitting brilliant vortical γ-ray pulses in the QED regime by CP lasers

With QED

Without QED



Vortex γ-ray photons



- **Femtosecond duration (40 fs);**
- **Relatively small polar angle (0.2 rad);**
- **The photon energy can extend to 1.2 GeV;**
- **The radiation power (6.7PW);**
- **The brightness at 15 MeV**

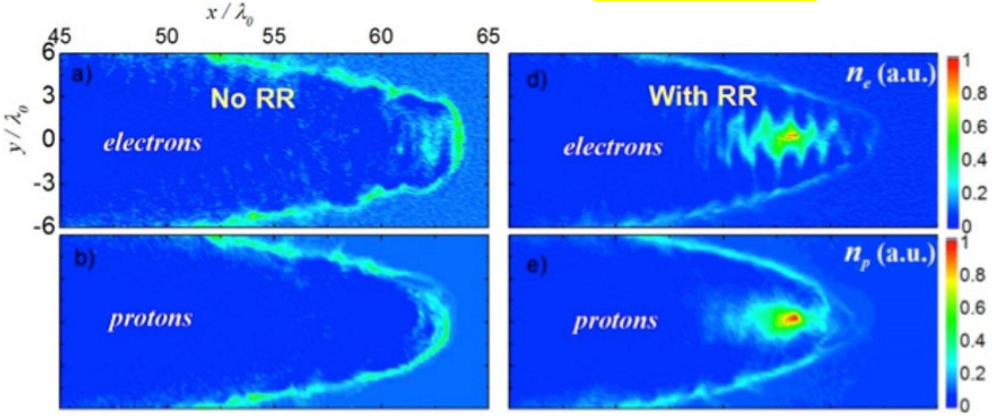
$$3.5\times 10^{25} photons/s/mm^2/mrad^2/0.1\%BW$$

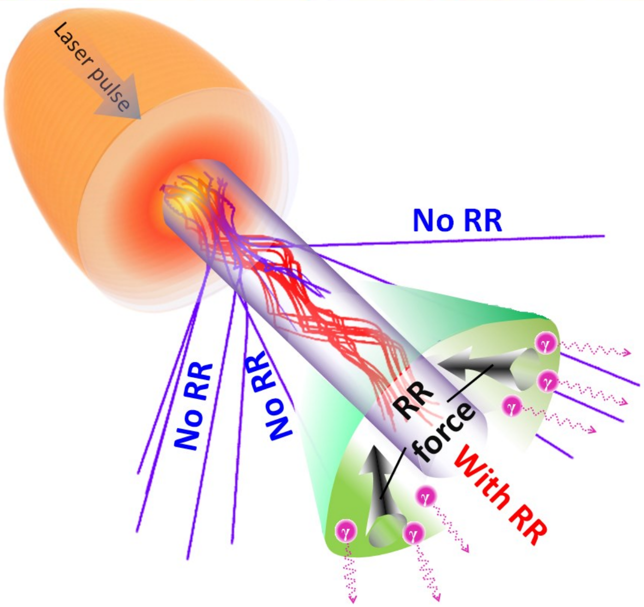
H. X. Chang et al., Scientific Reports 7, 45031 (2017)

Radiation-reaction trapping (RRT)

L-I 31: Liangliang Ji

No RR **With RR**





Radiation Reaction trapping effect is discovered in the near-QED regime when the expelling Lorentz force is balanced by the RR force.

$$F_{L,y} \sim F_{rr,y}$$

$$a_{thr} \sim (2k_p\omega_0 r_e/3c)^{-1/3} \sim (r_0/r_e)^{1/3}$$

- **RRT significantly change the LPI in the near-QED regime.**
- **Leads to efficient emission of Gamma-photons**

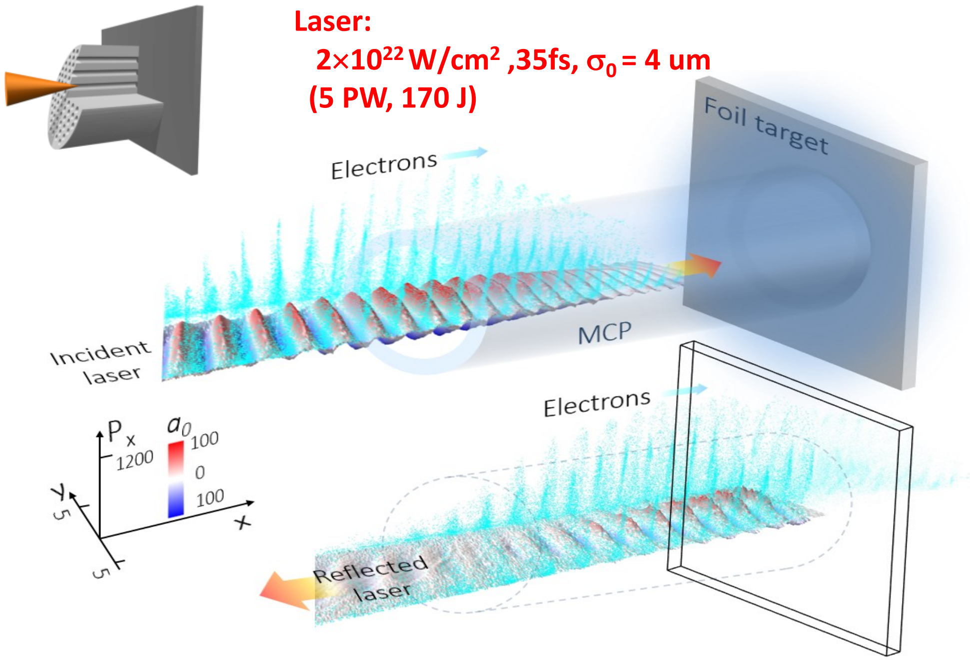
$$\frac{d\mathbf{p}}{dt} = \mathbf{F}_L + \mathbf{F}_{rr}$$

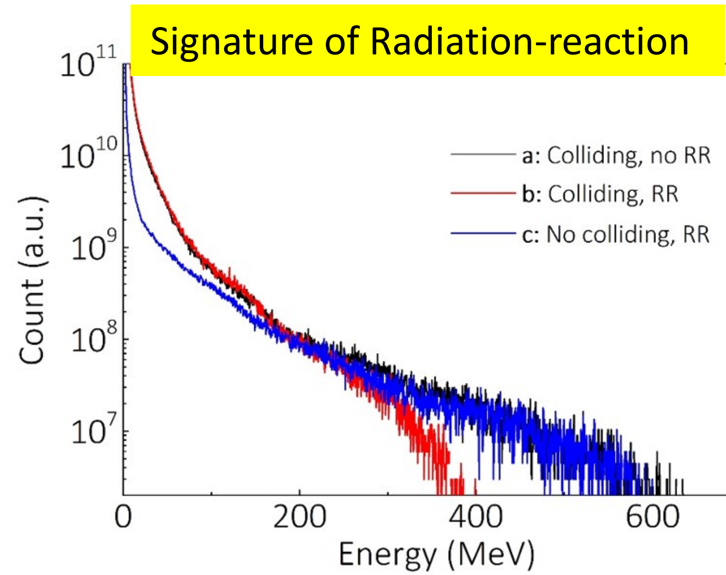
$$\mathbf{F}_{rr} \approx -(2e^4/3m_e^2c^5)\gamma^2\mathbf{v}\left[(\mathbf{E}+\mathbf{v}\times\mathbf{B}/c)^2 - (\mathbf{E}\cdot\mathbf{v})^2/c^2\right]$$

$$\mathbf{F}_L = -e(\mathbf{E}+\mathbf{v}\times\mathbf{B}/c)$$

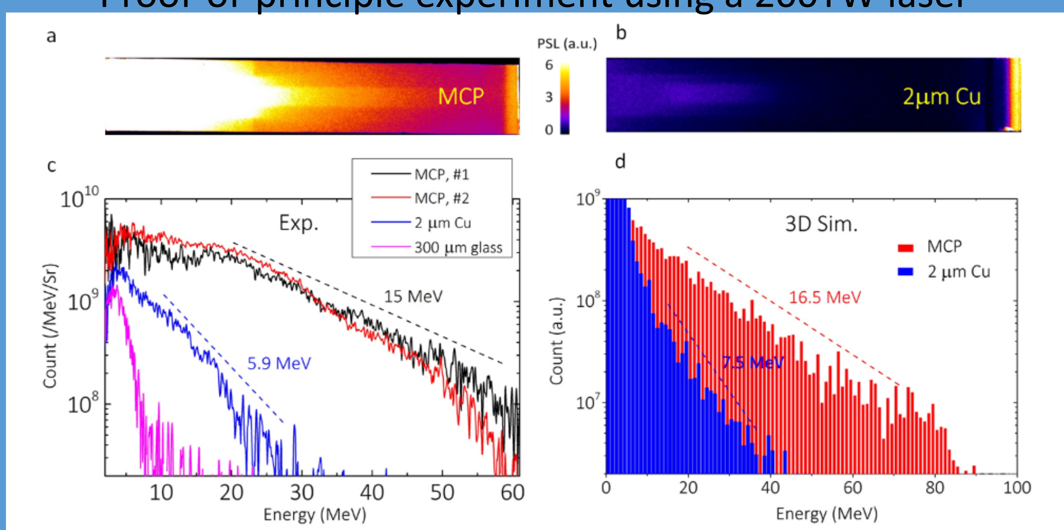
Ji et al., Phys.Rev.Lett. 112, 145003 (2014).

Laser-electron collider within a micro-channel





Proof-of-principle experiment using a 200TW laser



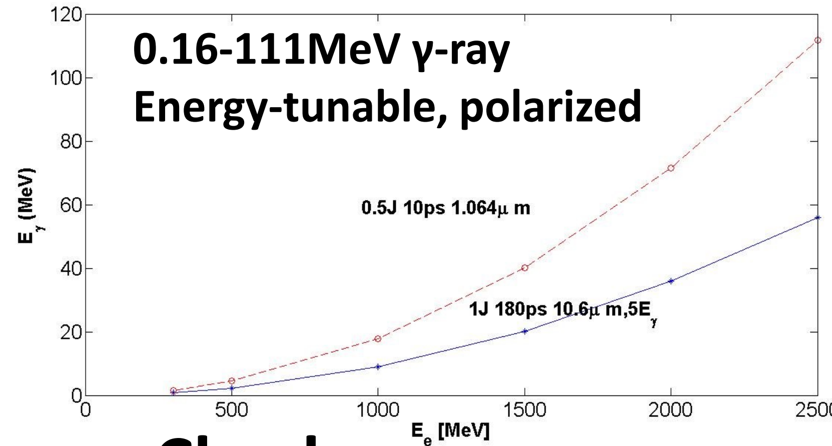
- A laser-electron collider is proposed by coupling one-single multi-PW laser system with micro-channel structure.
- First proof-of-principle experiment with 200 TW laser verifies the advanced electron source from micro-channel structure.

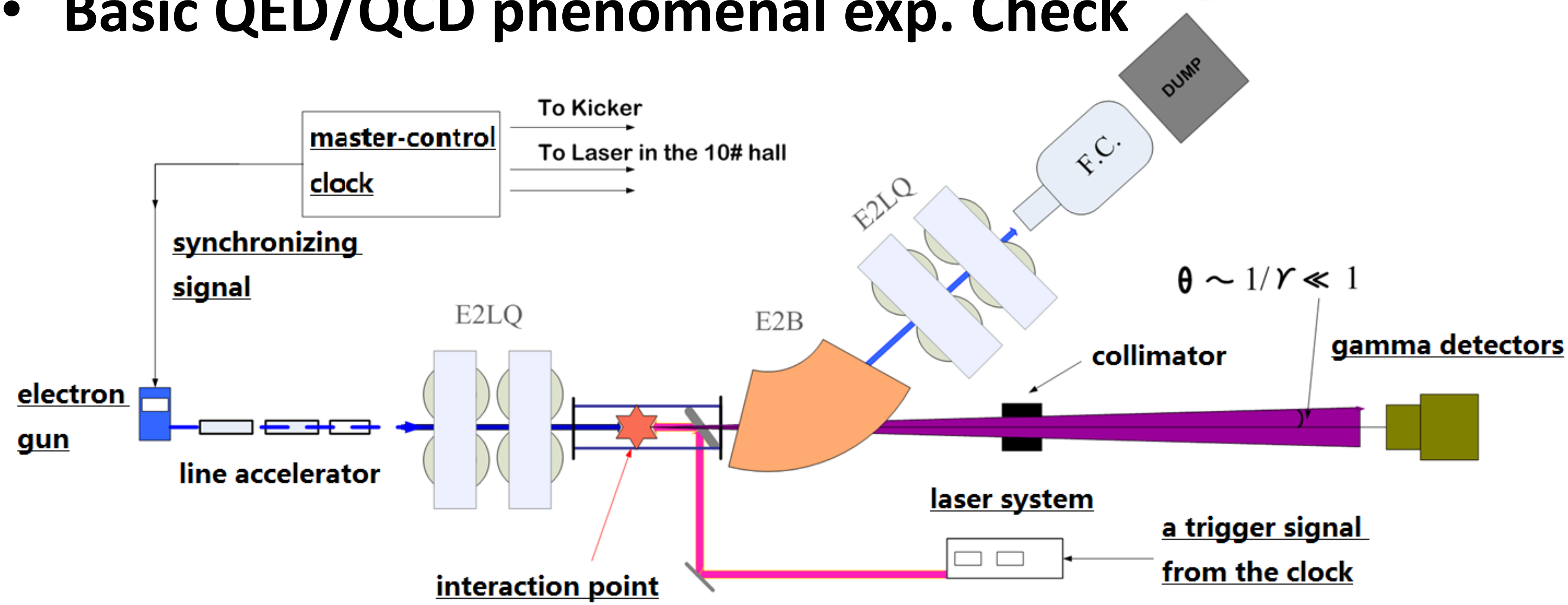
L-I 31: Liangliang Ji

Laser-compton scattering gamma-ray source based on BEPCII

L-I33: Y. Huang

- X-ray/γ-ray calibration
- Photon-nuclear physics
- Nuclear astrophysics
- γ-γ collider
- Basic QED/QCD phenomenal exp. Check

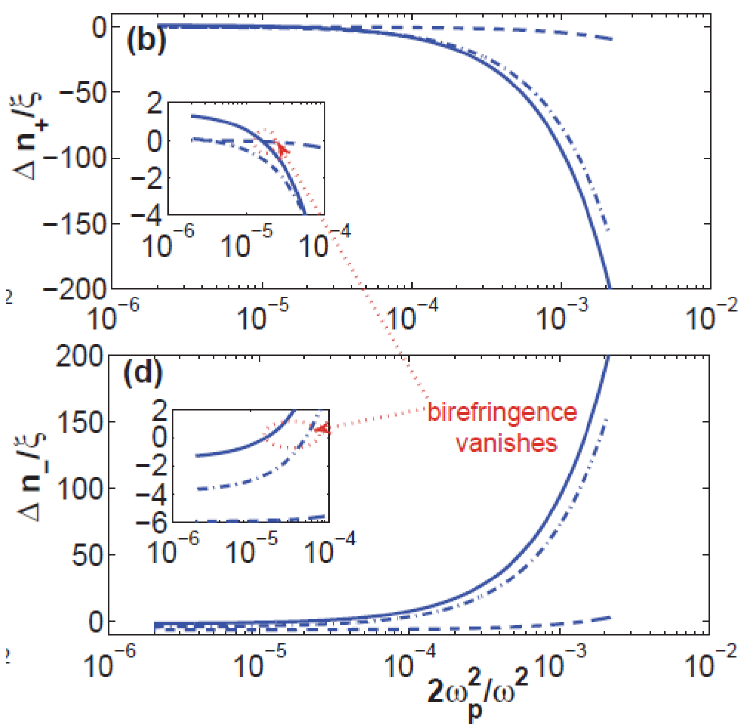




Ultra-intense laser+relativistic plasma -> to check QED effect in Plasmas

- QED effect cancels with the plasma effect:

$$\Delta n_{\pm} \approx \mp\hat{\omega}_p^2 \pm \frac{3}{2}(1 \mp \beta_0)^2\xi,$$



To estimate the thickness of the magnetosphere of a millisecond pulsar:

$$L_{B,ms} = C_{L,\psi}\frac{\lambda}{(1 \pm \beta_0)^2 B_0^2}\psi_{max,\lambda},$$

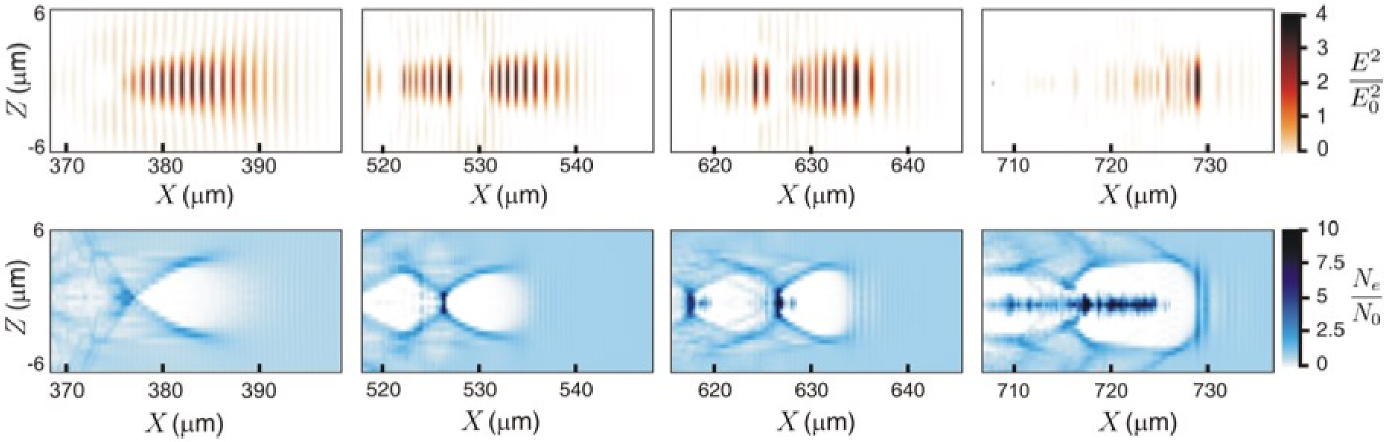
To estimate the plasma density of a pulsar:

$$n_0 \approx C_{n,B}\left(1 \pm \beta_0\right)^2 \frac{B_0^2}{\lambda_{c,l}^2} = C_{\omega,B}\omega_{c,l}^2\left(1 \pm \beta_0\right)^2 B_0^2,$$

Yongsheng Huang, Scientific Reports, 2015,5:15866

Photon deceleration in the bubble regime

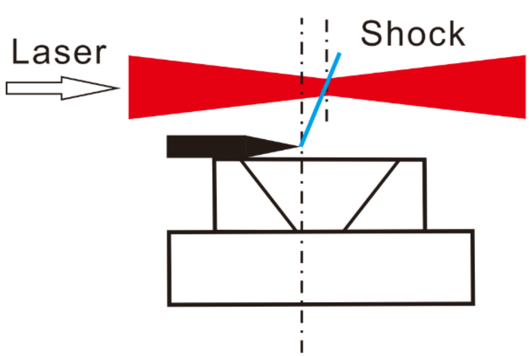
L-I5: Chi-hao Pai



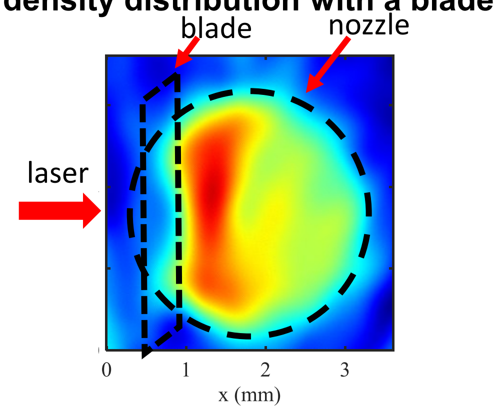
density modulation

$$\Delta n = \sqrt{1 - \frac{{\omega_p}^2}{\omega^2 \sqrt{1 + a^2/2}}} - \sqrt{1 - \frac{{\omega_p}^2}{\omega^2}}$$

relativistic self-phase modulation



density distribution with a blade

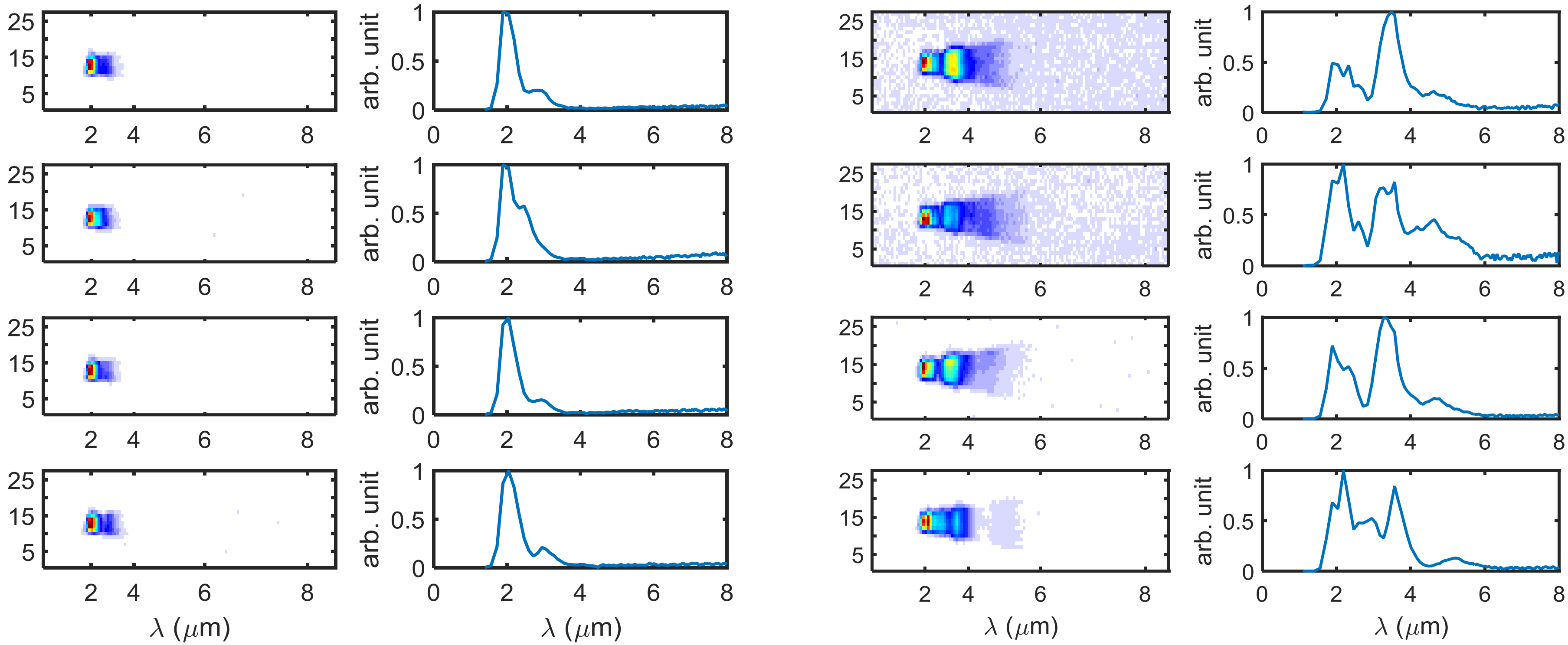


- The laser pulse undergoes strong self-phase modulation due to the longitudinal gradient of the refractive index in the plasma bubble. If the laser pulse completely resides in the first half of the plasma wave, its frequency can be completely down-shifted (photon deceleration).
- With a plasma structure, this photon deceleration process can be largely enhanced.

Photon deceleration in the bubble regime can be largely enhanced with a tailored plasma structure.

with uniform plasma measured spectrum

with plasma structures measured spectrum



30fs, 300mJ, 800nm, 10Hz Ti:sapphire laser

L-I5: Chi-hao Pai

- With plasma structures, under the optimal conditions, the energy of the generated mid-IR pulse in 2-8 μm wavelength range reaches 15.5mJ, corresponding to conversion efficiency as high as 5.2%.

Fundamental laser plasma physics

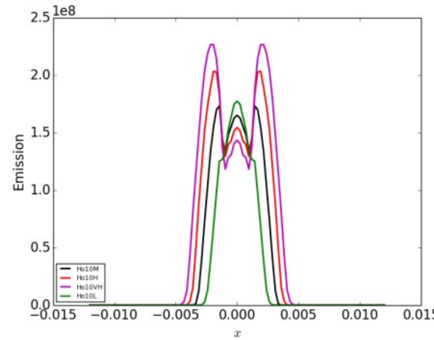
(fs-laser driven shocks, external magnetic control of plasma dynamics, nonlinear plasma waves)

Hydrodynamics Driven by Intense short-pulse lasers,

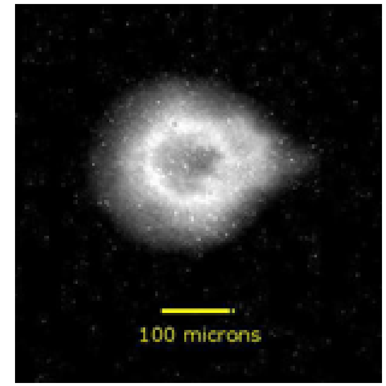
L-I 28

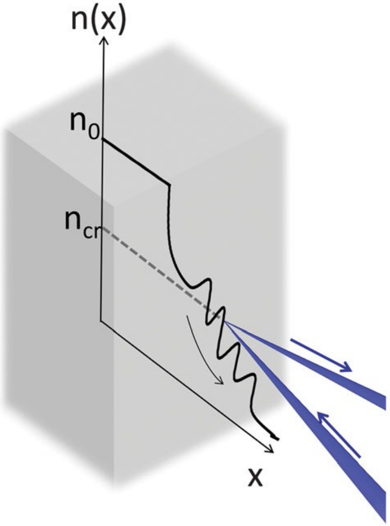
J. Pasley[1] et al
[1] York Plasma Institute, University of York

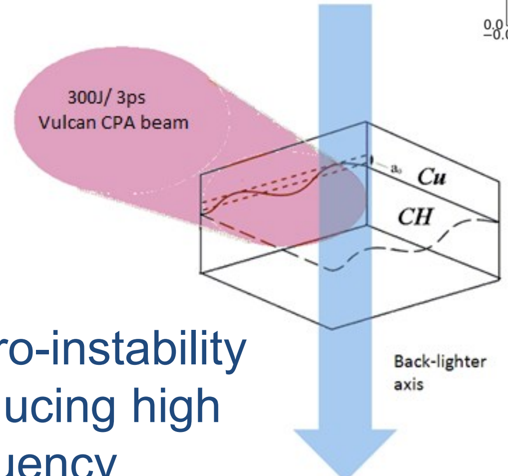
(Please see next slide for bibliography/ major institutional collaborators)



Ring-like XUV signature of shock propagation from central hotspot

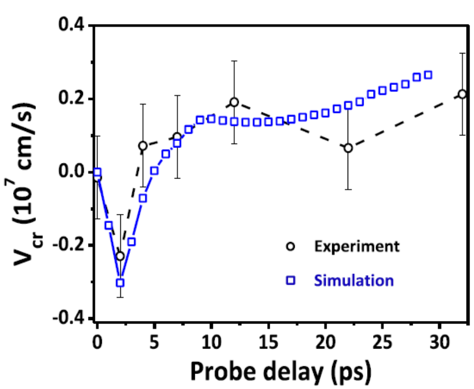


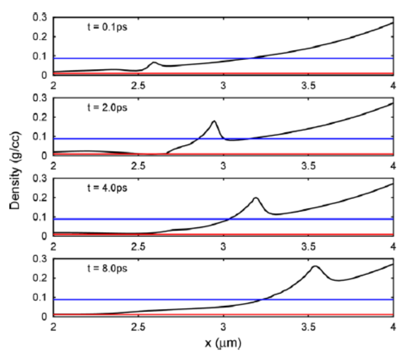




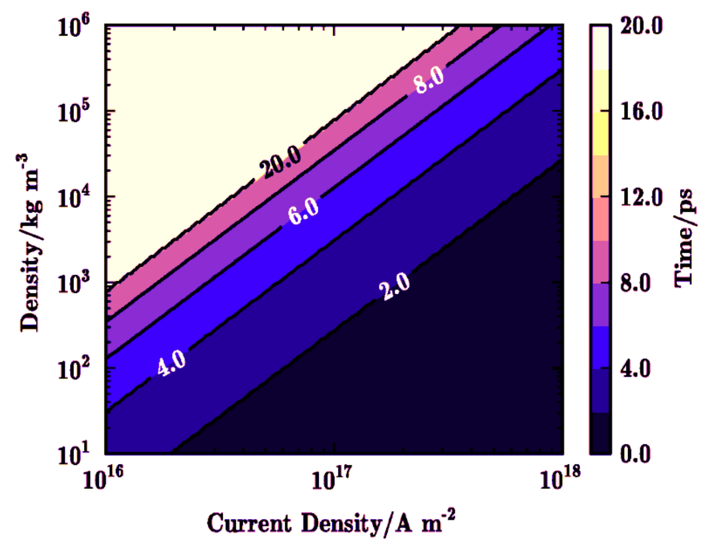
Non-ablatively stabilised RT growth driven by radiative cooling

Hydro-instability producing high frequency soundwaves





Shock formation



Hydrodynamics Driven by Intense short-pulse lasers

L-I 28

J. Pasley
York Plasma Institute, University of York

1. *K. L. Lancaster et al, Phys. Plasmas **16**, (2009)*
2. *S. Mondal et al, Phys. Rev. Lett. **105**, (2010)*
3. *I.A. Bush, A.P.L. Robinson, R. Kingham and J.Pasley, PPCF **52**, (2010)*
4. *A.P.L.Robinson, H.Schmitz, and J. Pasley, Phys. Plasmas **20**, (2013)*
5. *A. Adak et al, Phys. Plasmas 21, (2014)*
6. *A. Adak et al, Phys. Rev. Lett. 114, (2015)*
7. *A.P.L. Robinson et al, Phys. Plasmas **22**, (2015)*
8. *A. Adak et al, Phys. Plasmas **24**, (2017)*
9. *K.L. Lancaster et al, Phys. Plasmas **24**, (2017)*
10. *K.U. Akli (LLNL, GA, OSU), et al, Phys. Rev. Lett. 100, (2008)*

tifr FDTN FUSION DOCTORAL TRAINING NETWORK CLF central laser facility THE UNIVERSITY of York York Plasma Institute

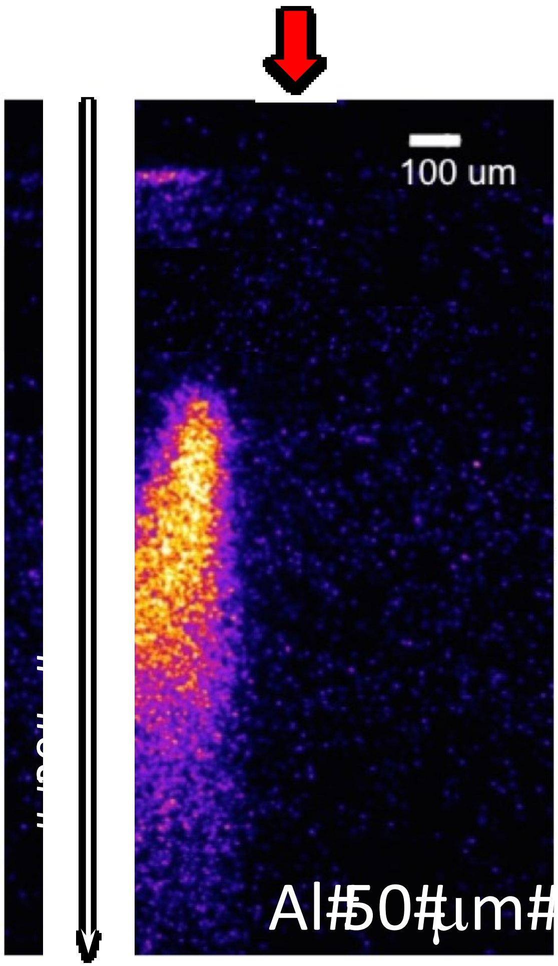
Generation of high-pressures in aluminium by femtosecond low-energy laser irradiation

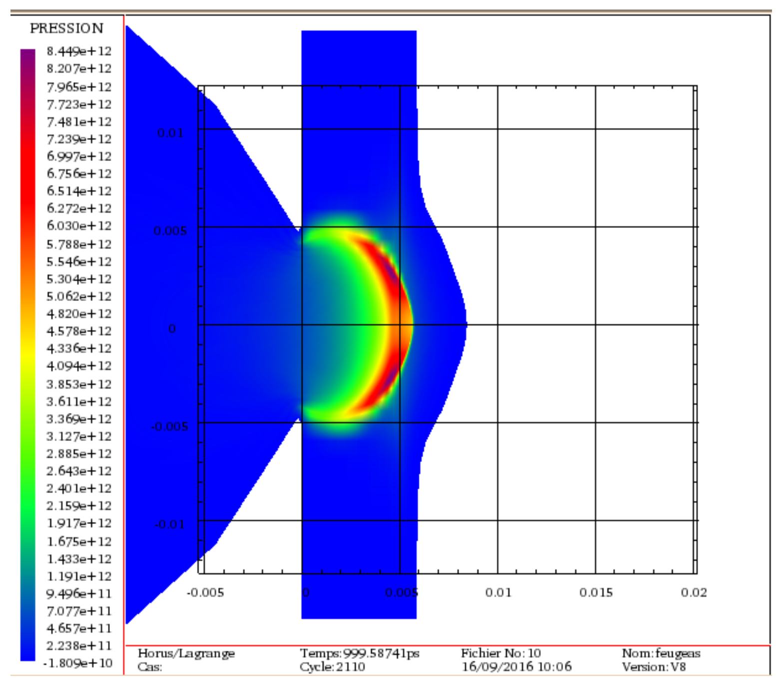
*K. Jakubowska, **D.Batani**, J.-F. Feugeas, P. Forestier-Colleoni, S. Hulin, P. Nicolaï, J.J. Santos, A. Flacco, B. Vauzour, V. Malka*

CELIA (Bordeaux), LOA (Palaiseau), IPPLM (Warsaw)

L-O 6

LASER&





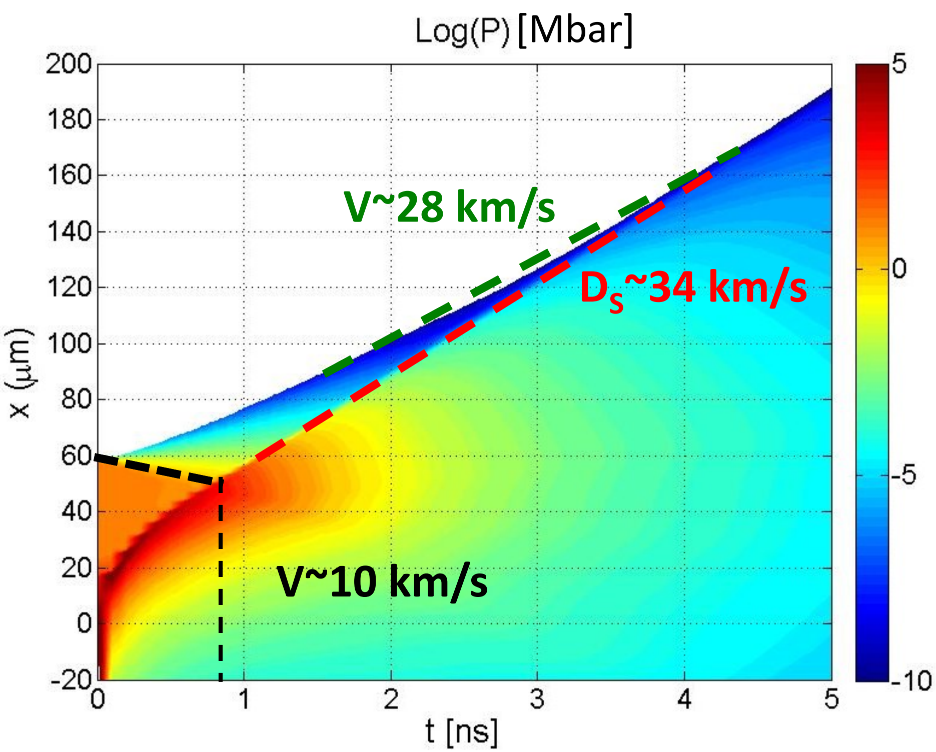
Formation of a blast wave

1D hydro simulations performed with the code CHIC

Highlights of the experiment:

L-O 6, D Batani

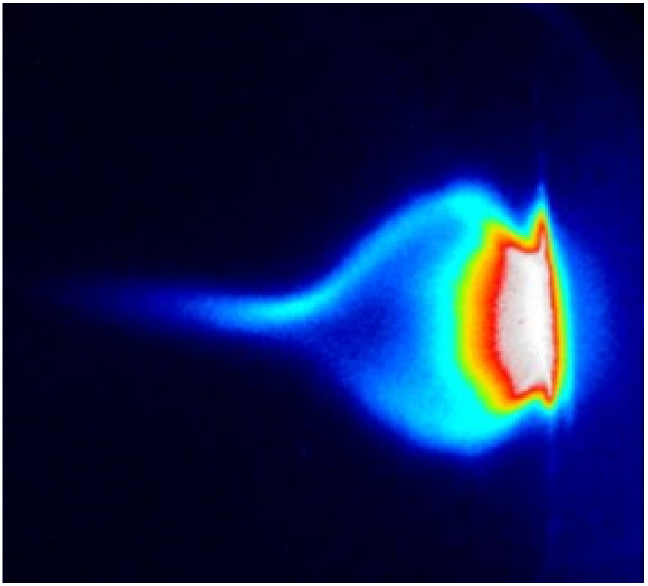
- ✓ Very strong pressures using a short-pulse high-intensity laser (initially ≥ 100 Mbar);
- ✓ The shock has a BLAST WAVE structure and the pressure rapidly decreases to ≤ 1 Mbar at shock breakout
- ✓ There is a complex shock dynamics dominated by the effects of target expansion. The shock has constant velocity;

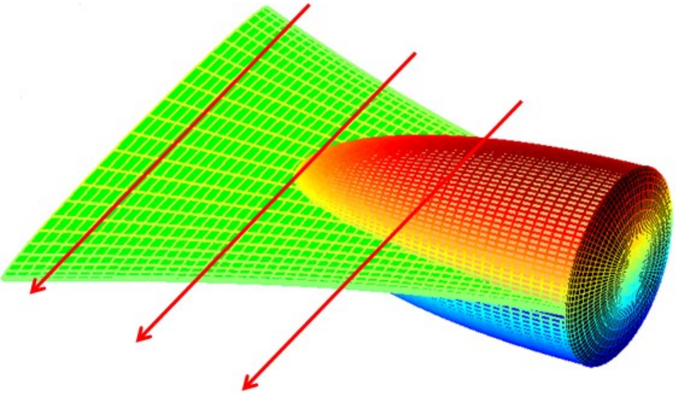


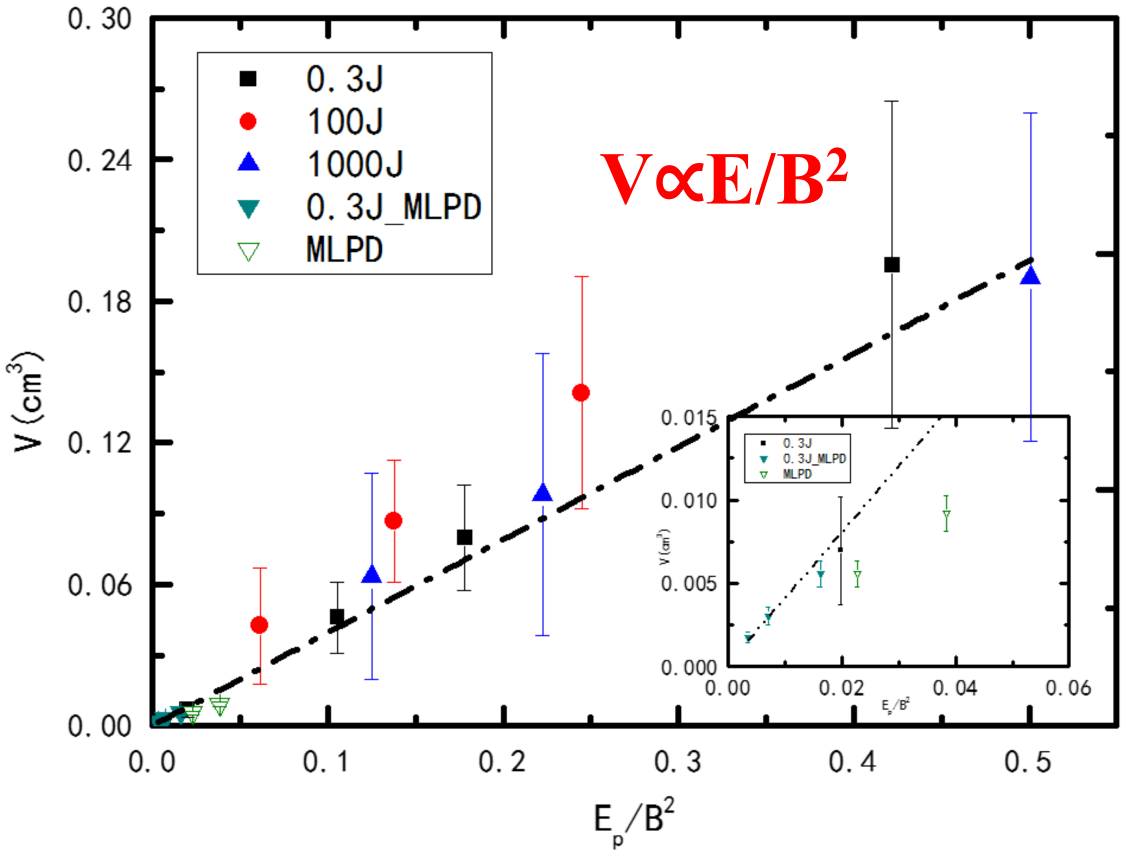
- ✓ Due to target decompression the blast wave is lost along the axis but the blast wave structure is maintained out of axis;
- ✓ We measured the color temperature at shock breakout which resulted in good agreement with CHIC simulation.
- ✓ HED states can be created and probed with short-pulse high-intensity lasers
- ✓ It will be possible to perform studies on blast waves with implications for astrophysics

B field can replace gas filled in hohlraum to confine plasma expansion

L-I29: Guangyue Hu (USTC, China)



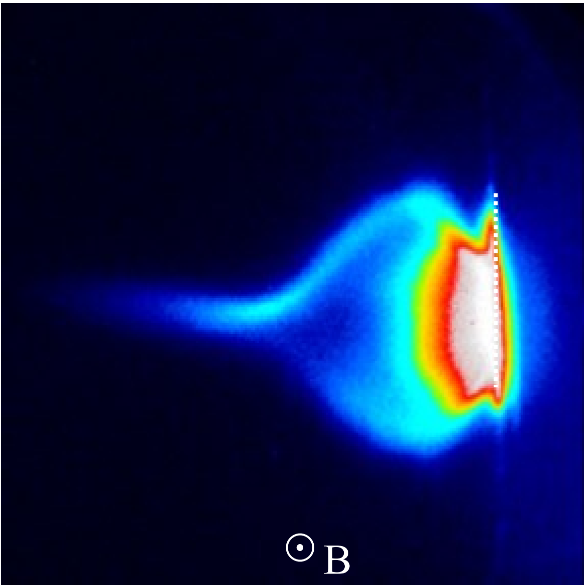


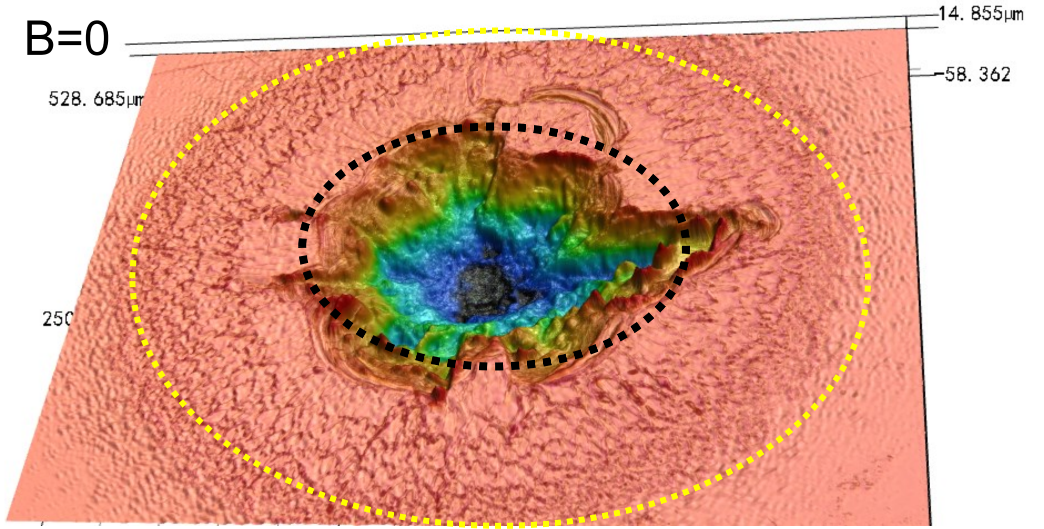


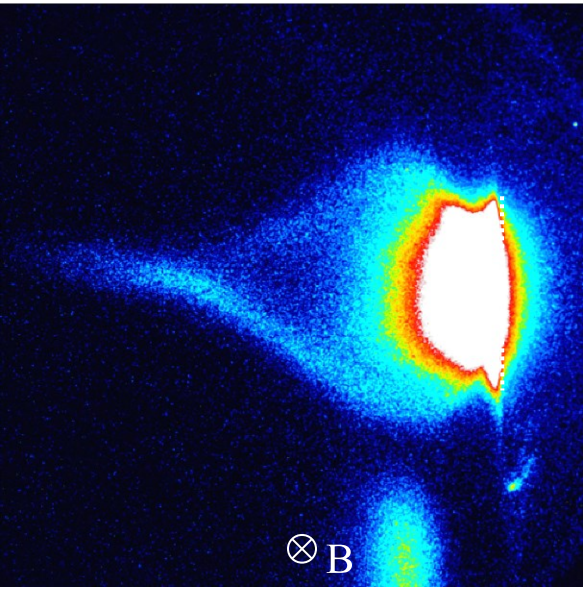
- 15% of the absorbed laser energy converts into B field energy
- Effective in 0.3-1000J laser energy

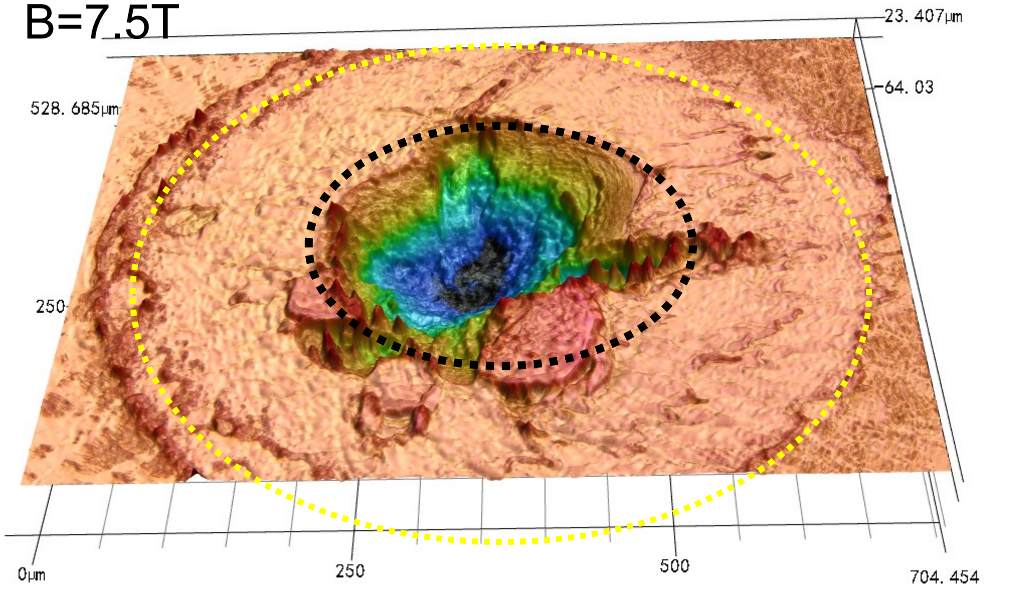
Hall effect caused asymmetric bubble
B field enhances ablation

L-I29: Guangyue Hu



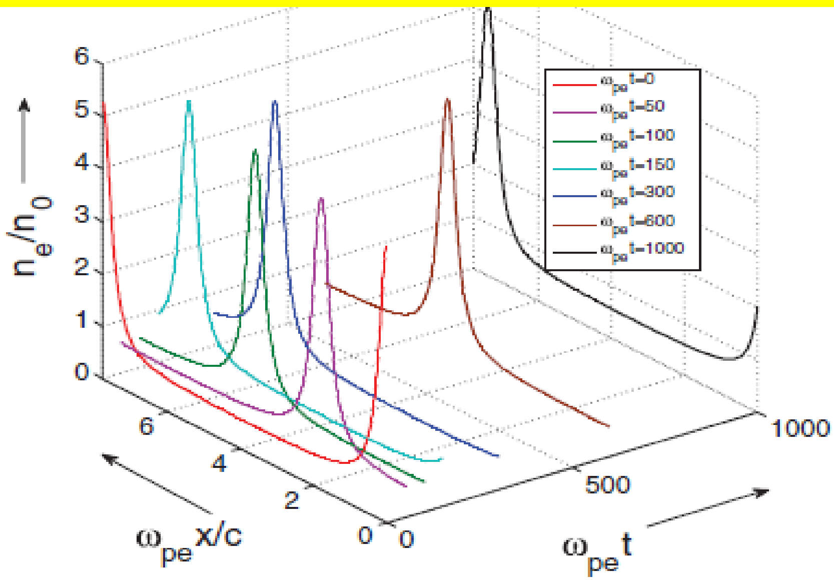




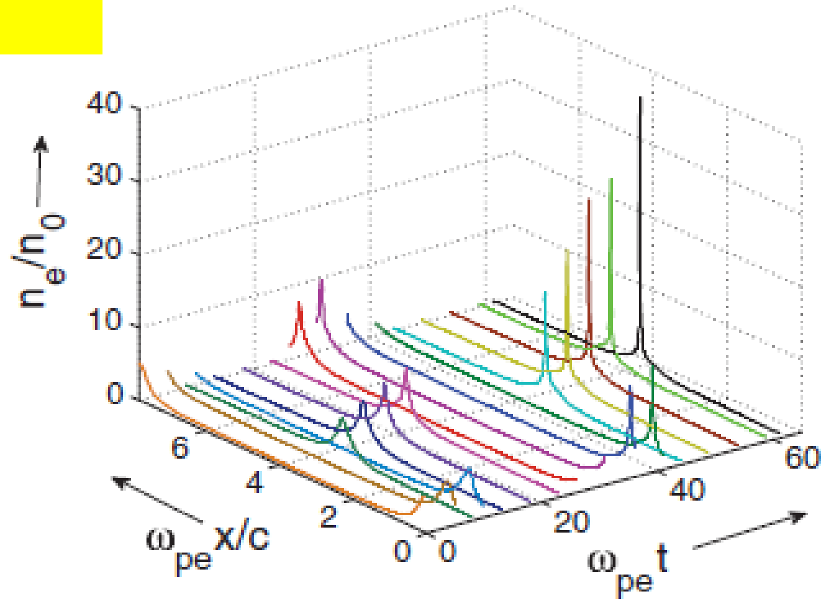


Wave breaking of Relativistically intense longitudinal waves in plasma - I (cold plasma)

L-I7: Sudip Sengupta (IPR, India)



Akhiezer-Polovin wave propagating through a cold plasma

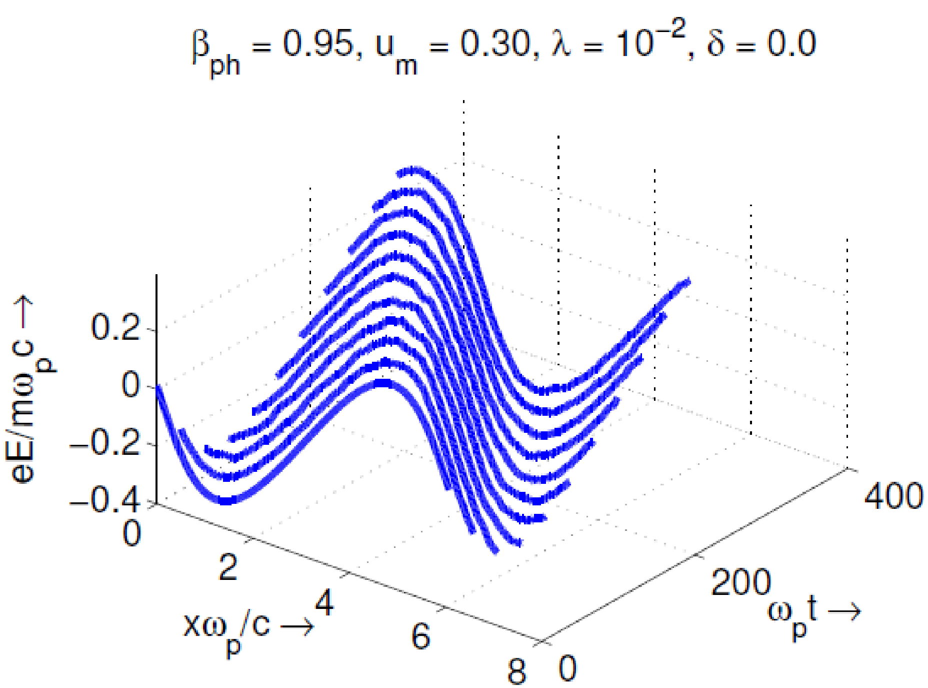


Perturbed Akhiezer-Polovin wave exhibiting wave breaking

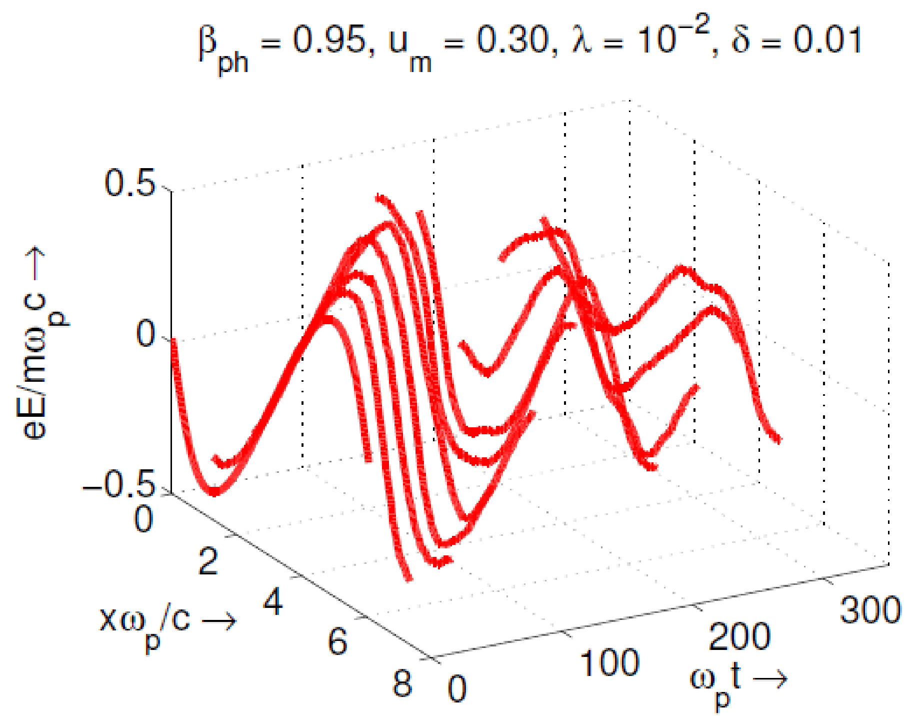
- *A longitudinal Akhiezer-Polovin wave breaks via phase mixing at an amplitude well below its wave breaking limit, when it is longitudinally perturbed.*
- *Therefore all those experiments which depend on Akhiezer-Polovin wave breaking limit for their interpretation will require revisiting.*

Phys. Rev. Lett. 108, 125005 (2012)

Wave breaking of Relativistically intense longitudinal waves in plasma - II (Warm plasma)



Wave propagating through a warm plasma (with a Jüttner distribution)



Perturbed wave in a warm plasma exhibiting wave breaking

- *Longitudinal waves in a warm plasma also break via the process of phase mixing.*
- *Therefore there is no real wave breaking limit for a longitudinal wave in a warm plasma.*

Summary

- New fusion concepts remain an important topic.
- Laboratory astrophysics and high energy density physics are emerging frontiers
- Short pulse laser-plasma interaction and their applications are pursued widely in Asian countries
- New technologies related with ultra-high power lasers, diagnostics, and magnetic field push the laser-plasma interaction to new regimes.

Many thanks to laser-plasma program speakers!

Thank you for your attention!