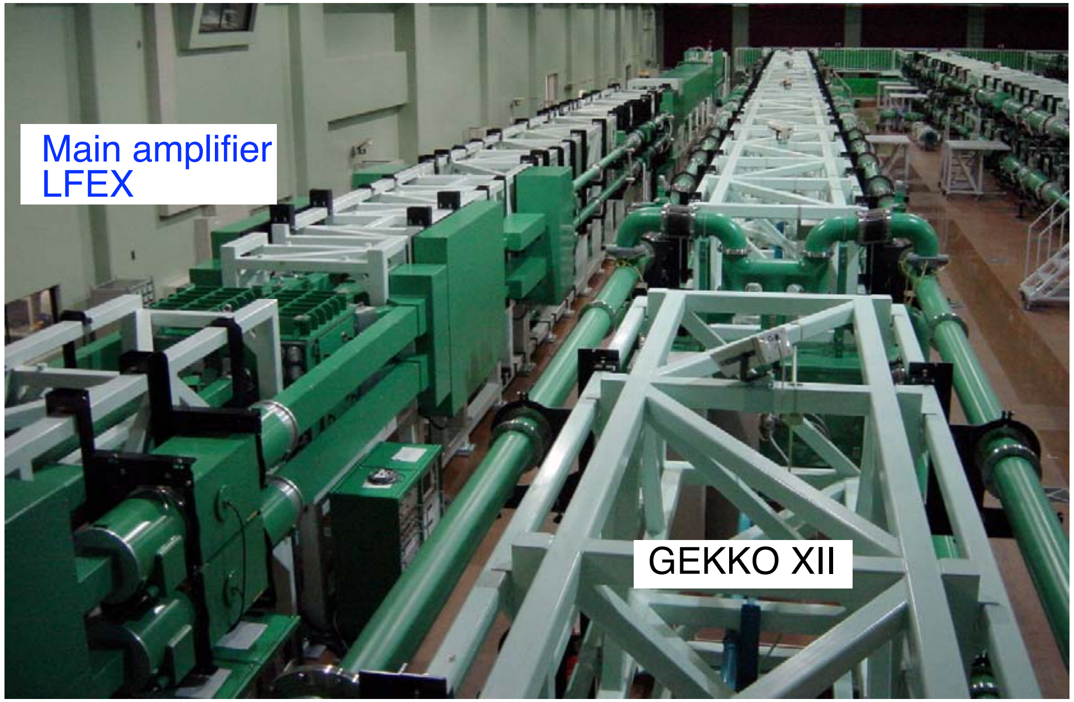
Laser Plasma Simulations related to Fast Ignition



Institute of Laser Engineering, Osaka University

K. Mima,

Co. with T. Johzaki, H. Nagatomo, H.B.Cai, W.M.Zhou

ICUIL, 28, October, 2008 at Tongli, Shanghai, China

Outline

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1. Introduction for fast ignition laser fusion
2. Critical issues of electron driven fast ignition
3. Reduction of hot electron divergence
4. Electron transport in a double cone
5. Concluding remarks

Fast ignition is attractive because of high gain with a small laser.

- Compression and Heating are separated -

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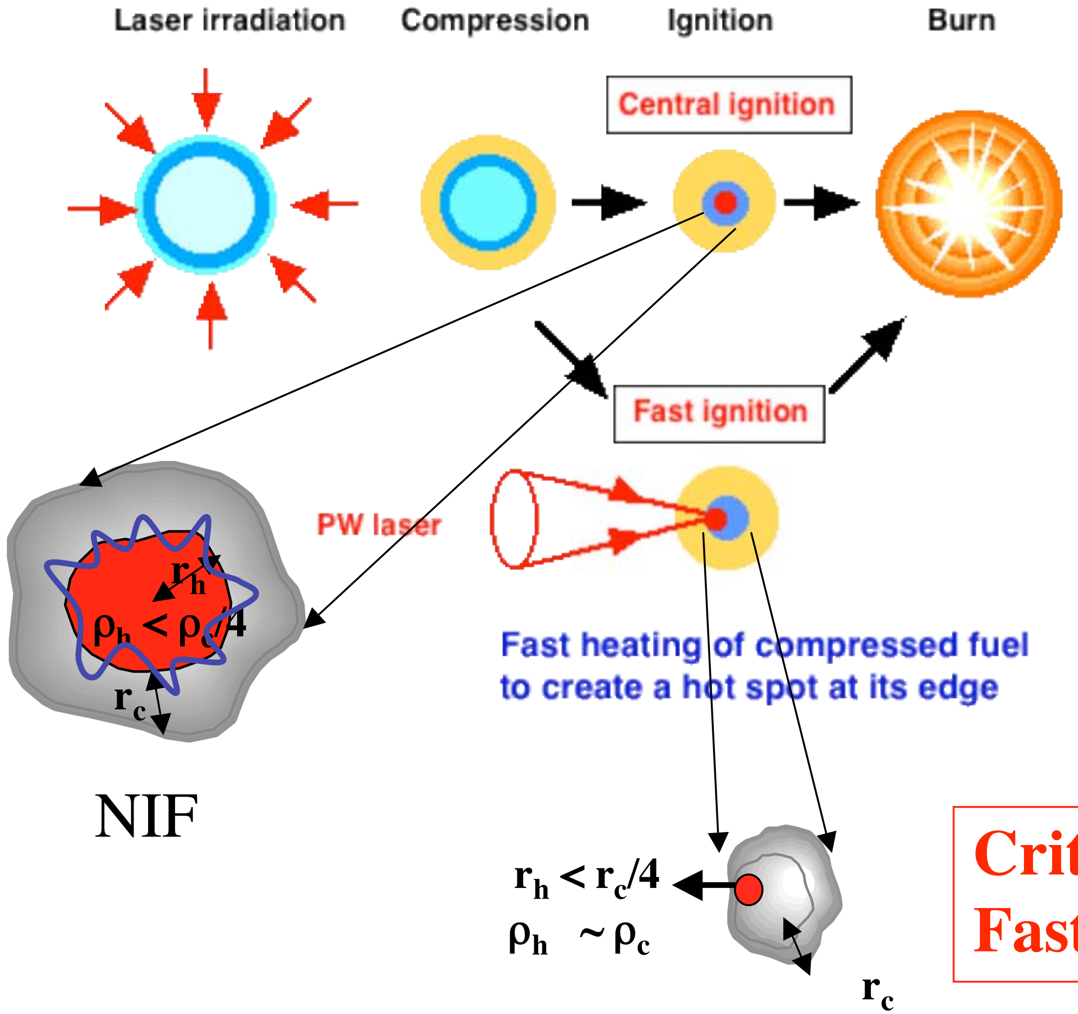
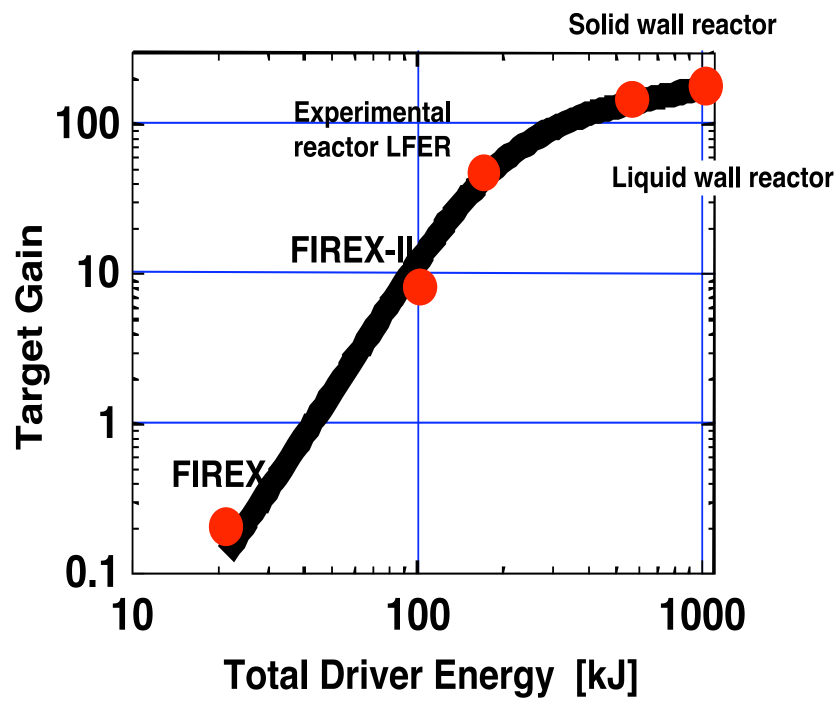


FIREX, OMEGA-EP, HiPER, NIF-ARC---



Critical issue is core plasma
Fast heating by Peta watt laser.

Rapid Progress of High Intensity Lasers

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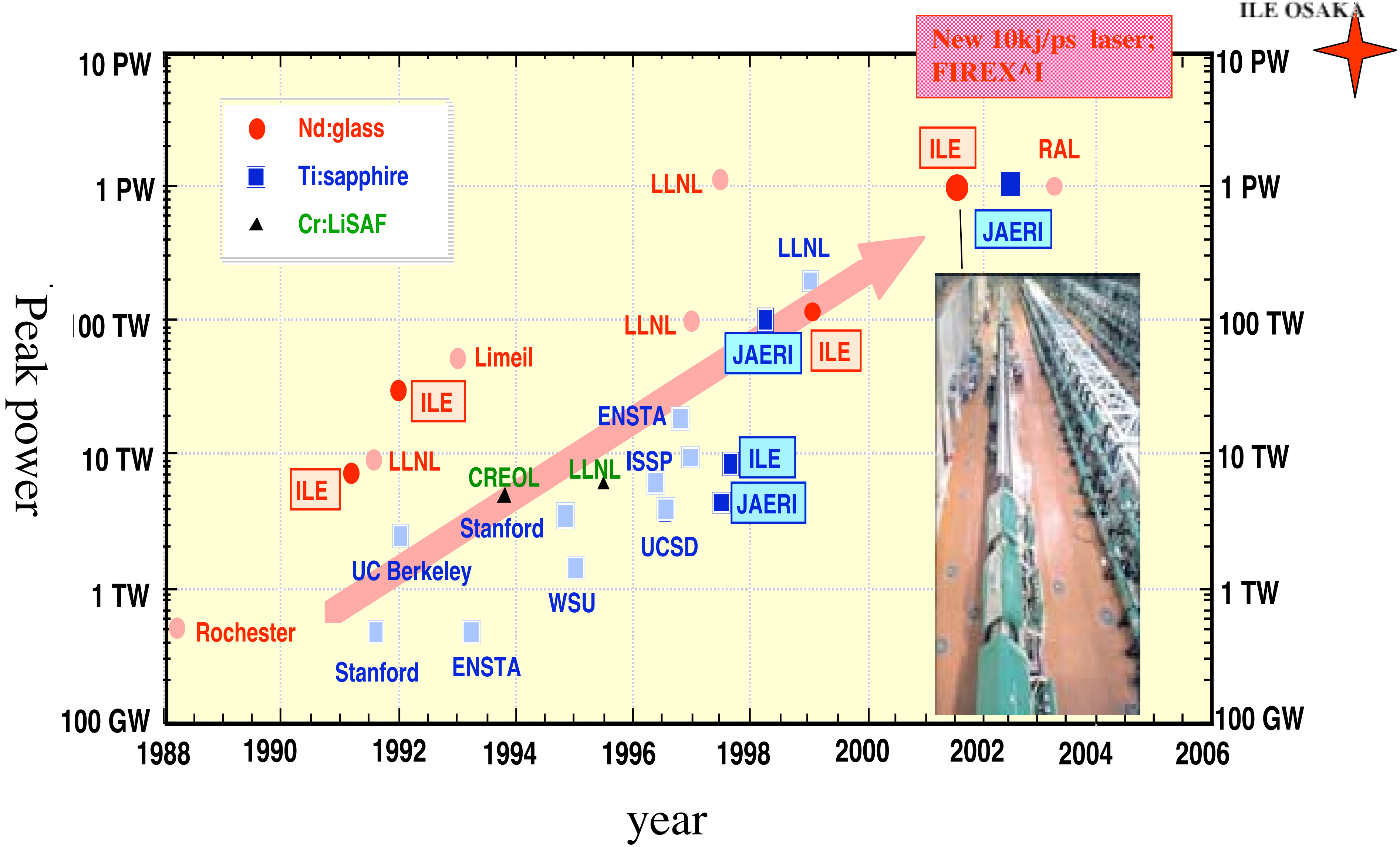

Construction Status of LFEX PW Laser

N. Miyanaga, H. Azechi, K. A. Tanaka[A], T. Kanabe[B], J. Kawanaka, Y. Fujimoto, K. Kondo[A], T. Jitsuno, H. Shiraga, K. Tsubakimoto, Y. Nakata, R. Kodama[A], H. Habara[A], K. Sueda, K. Yasukawa, J. Lu, G. Xu, N. Morio, S. Matsuo, S. Kitamura, K. Sawai, K. Suzuki, and K. Mima

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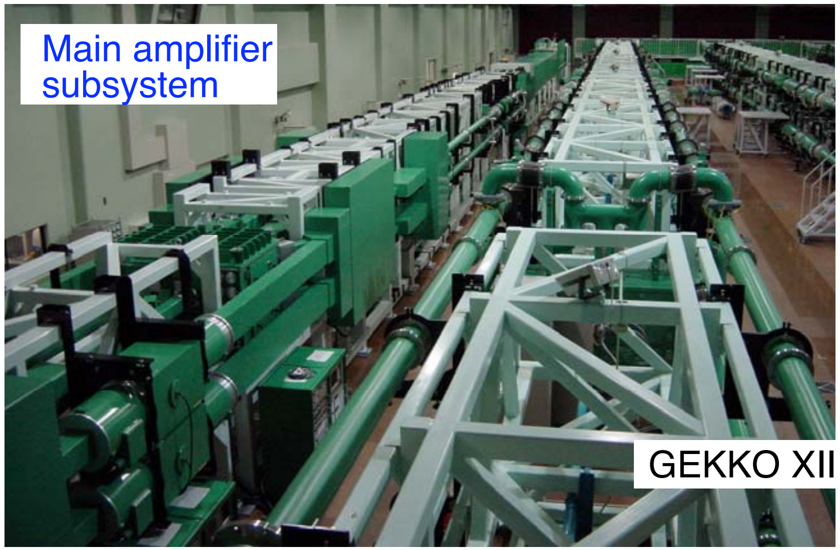
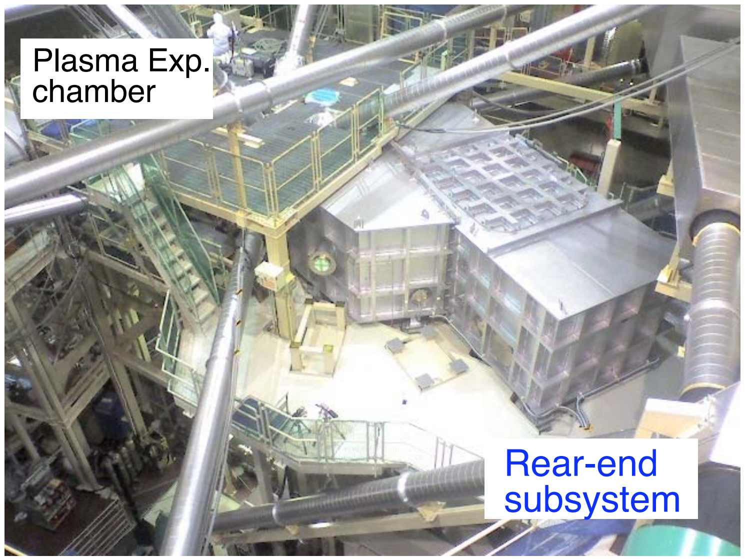
LFEX is the 10kJ/1ps laser with f = 6 and 370mmx370mm x 4 beam





Compressor Construction schedule toward 10kJ/1ps

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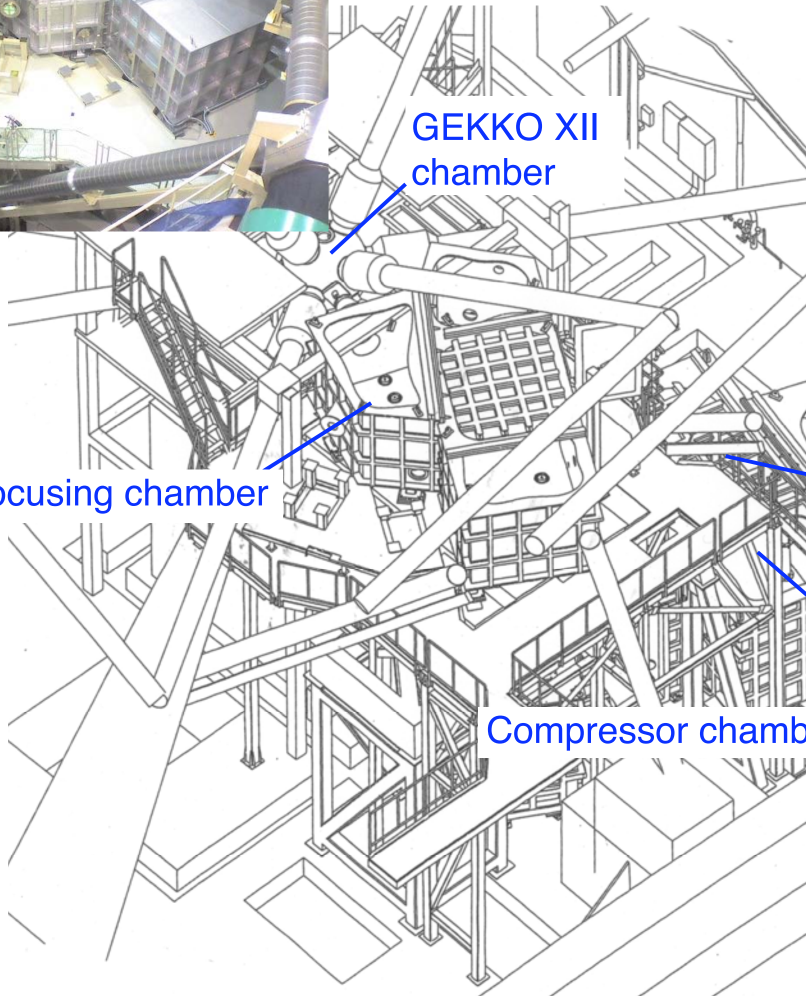
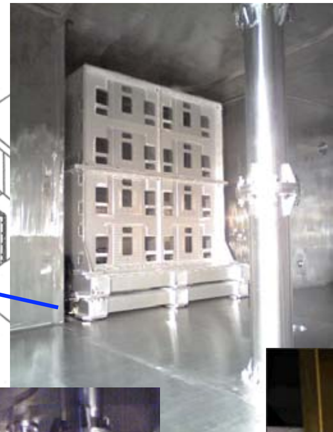
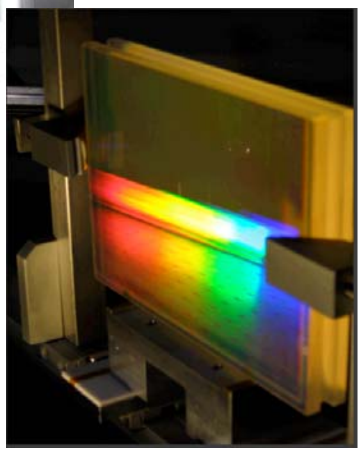
Y.2008
-Pulse compression / focusing (1 beam)
- 1 beam plasma experiment
Y.2009~
- Completion of 4 beams
- Performance improvements (Deformable mirrors in rear end)





Grating mechanics holder

91cmx42cm X16 from PGL



Optical Phase Lock by Tip-tilt/piston mirrors

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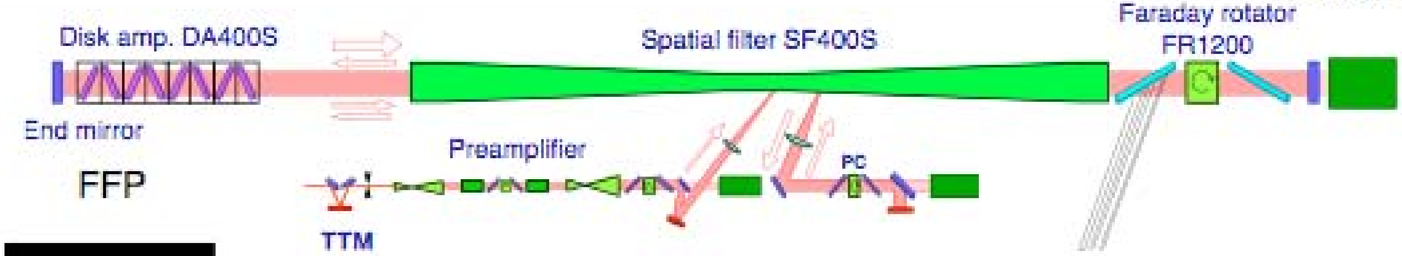
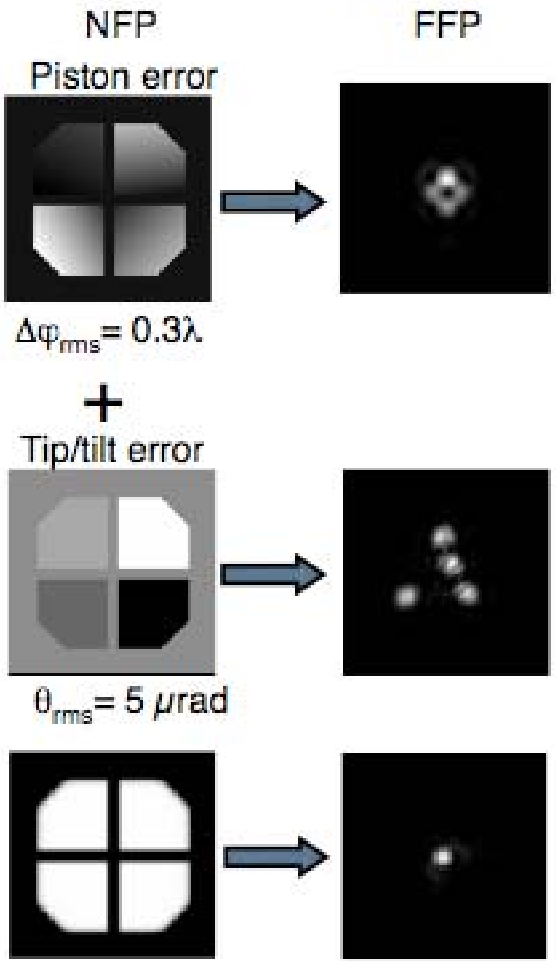
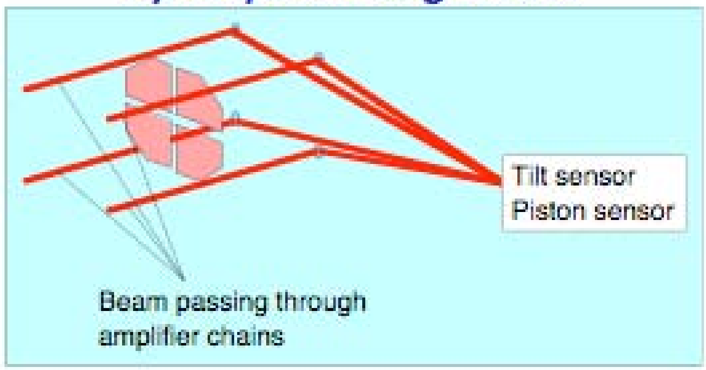




Tip-tilt/piston diagnostics



FI^3 project

Fast Ignition Integrated Interconnecting code

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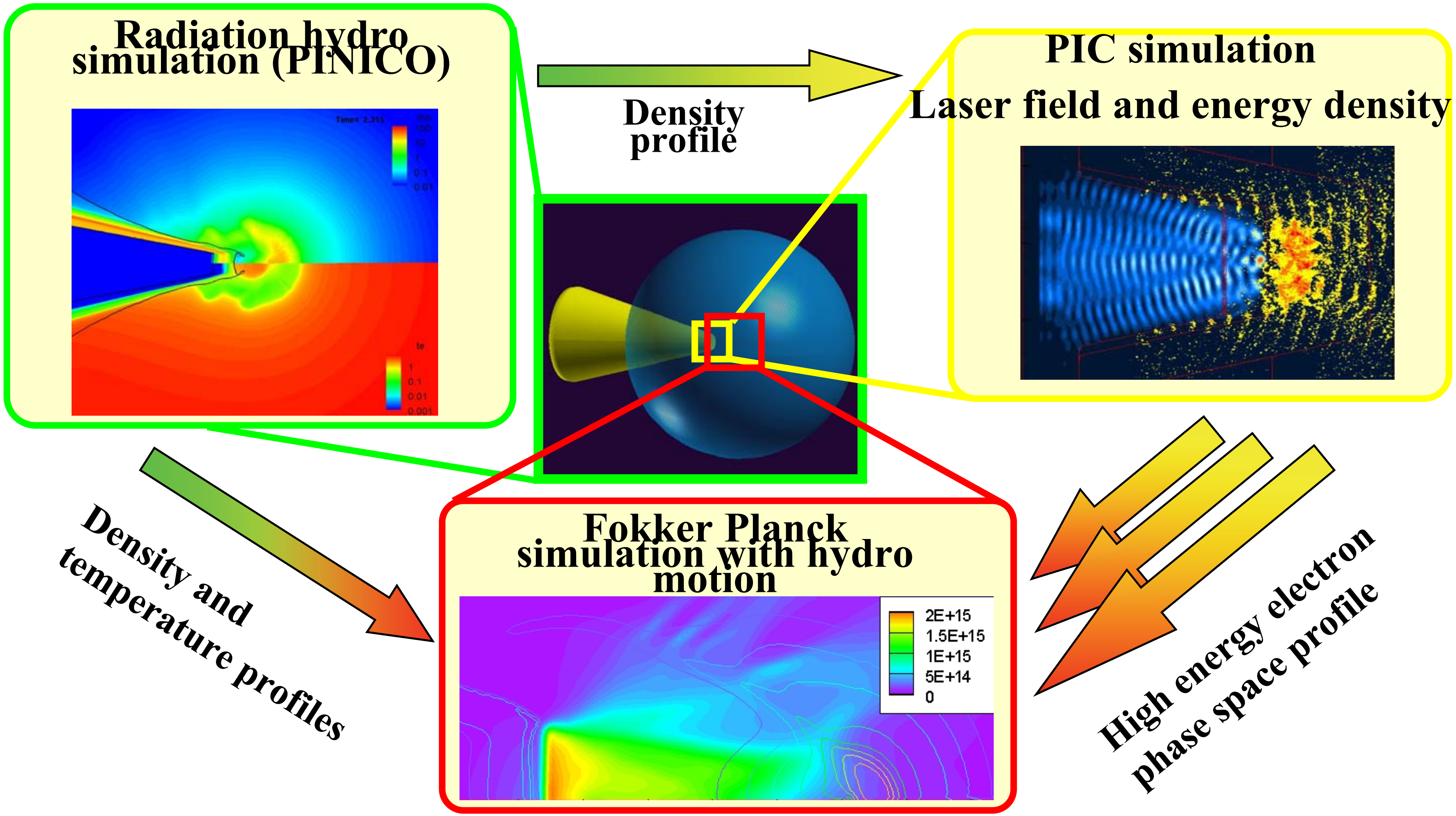
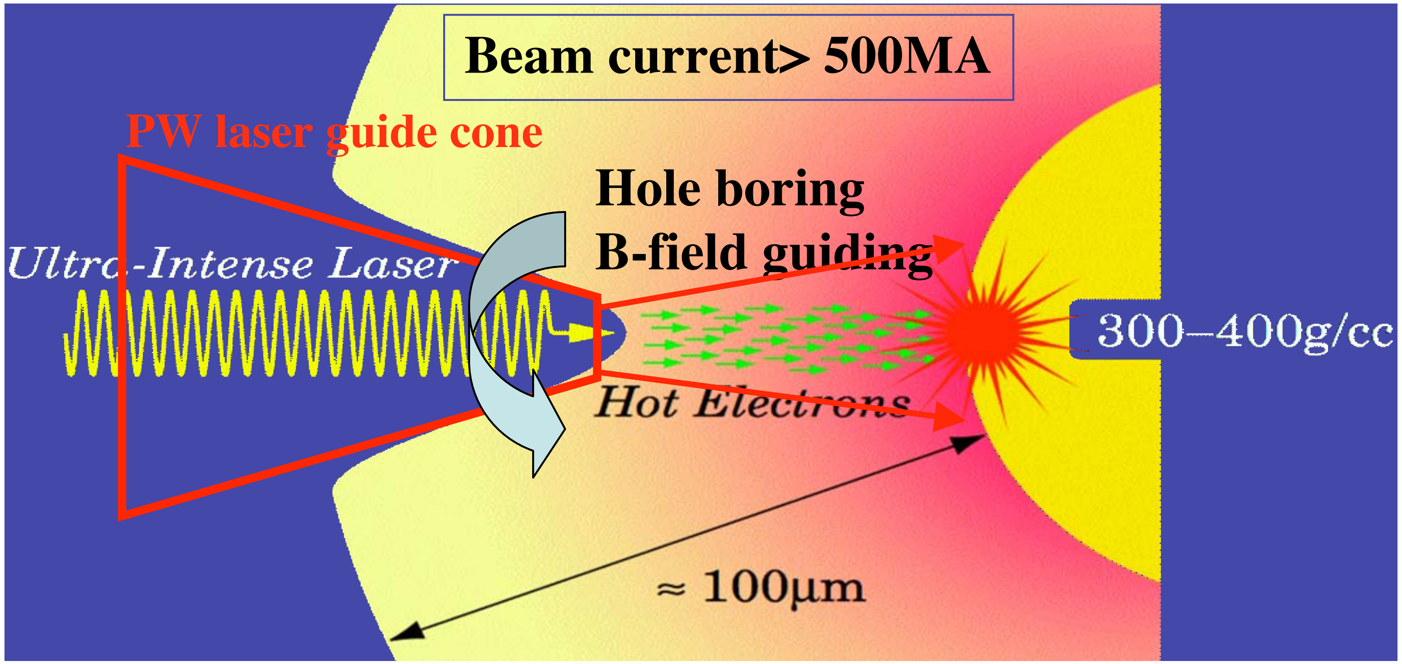


Collaboration; Osaka Univ. , NIFS, Kyushu Univ. Setunan Univ., Nevada Univ. Reno

Relativistic electron generation and transport are critical issues

Efficient coupling is critical; hole boring, cone target, magnetic electron guiding, and so on are considered.

Laser intensity; $I_L = 2x10^{15}$ W/ πr_h^2 ~ 1~2x 10^{20} W/cm2
Electron energy; $\varepsilon_r = (\gamma\text{-}1)mc^2$,
$\gamma_W = [1+ (eA/mc)^2]^{1/2} = [1+ I_L/(2.4x10^{18}W/cm^2)]^{1/2}$: So, ε_r ~ 3~5 MeV ?



Electron beam diameter dependence of required energy for ignition

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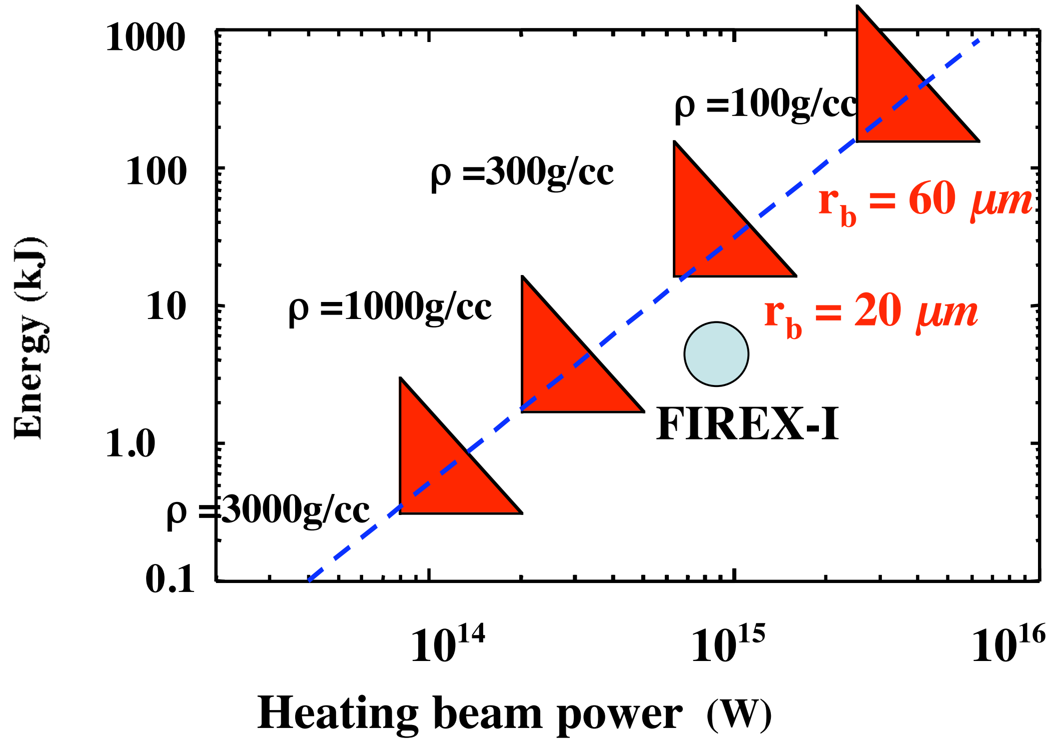
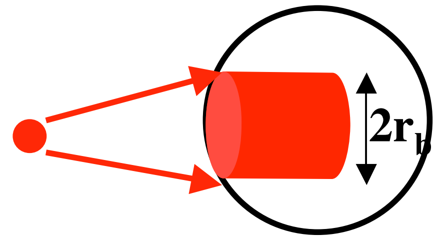




$E_b = 140\{\rho/(100g/cc)\}^{-1.85}$ kJ $\qquad P_b = 2.6\{\rho/(100g/cc)\}^{-1.0}$ PW

$I_b = 2.4X10^{19}\{\rho/(100g/cc)\}^{0.95}$ W/cm^2 $\qquad r_b = 60\{\rho/(100g/cc)\}^{-0.975}$ μm

Fixed e-beam stopping range: S.Atzeni, POP 1999

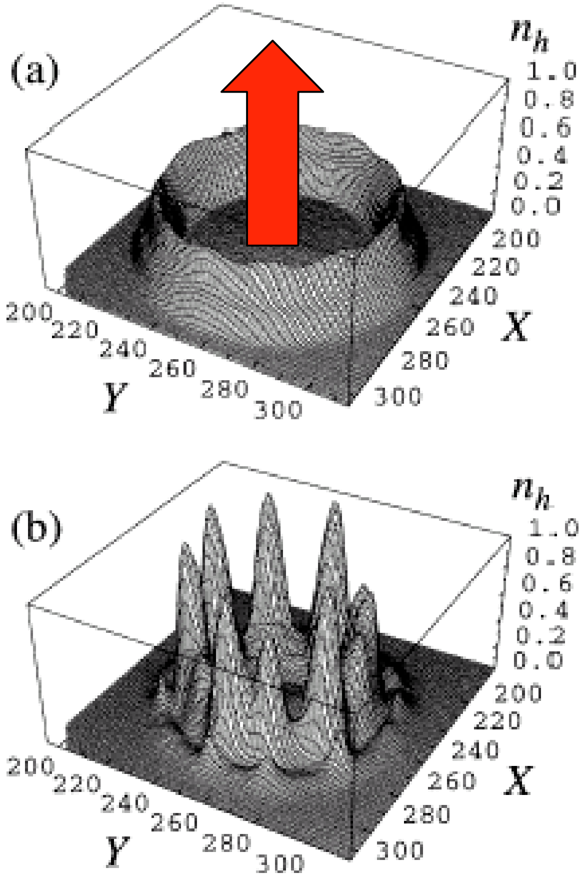
Cylindrical beam Weibel Instability
Seeded Weibel Instability
-stable propagation of hollow beam-

Cylindrical Weibel Insta. Transverse 2D

Taguchi et al.,
PRL 86, 5055 (2001)

$\omega_p t$ = 67

$\omega_p t$ = 81

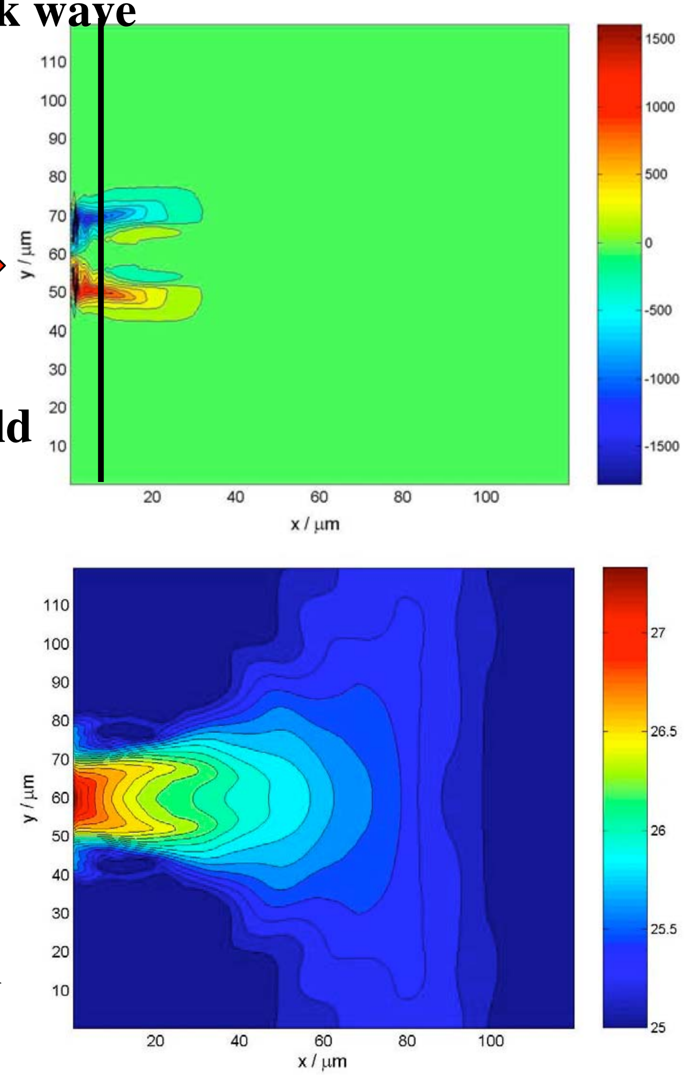


RAL proposal (P.Norreys IAEA, FEC 2008)

Shock wave

B field

n_h



Confining High Energy Electrons to increase coupling efficiency

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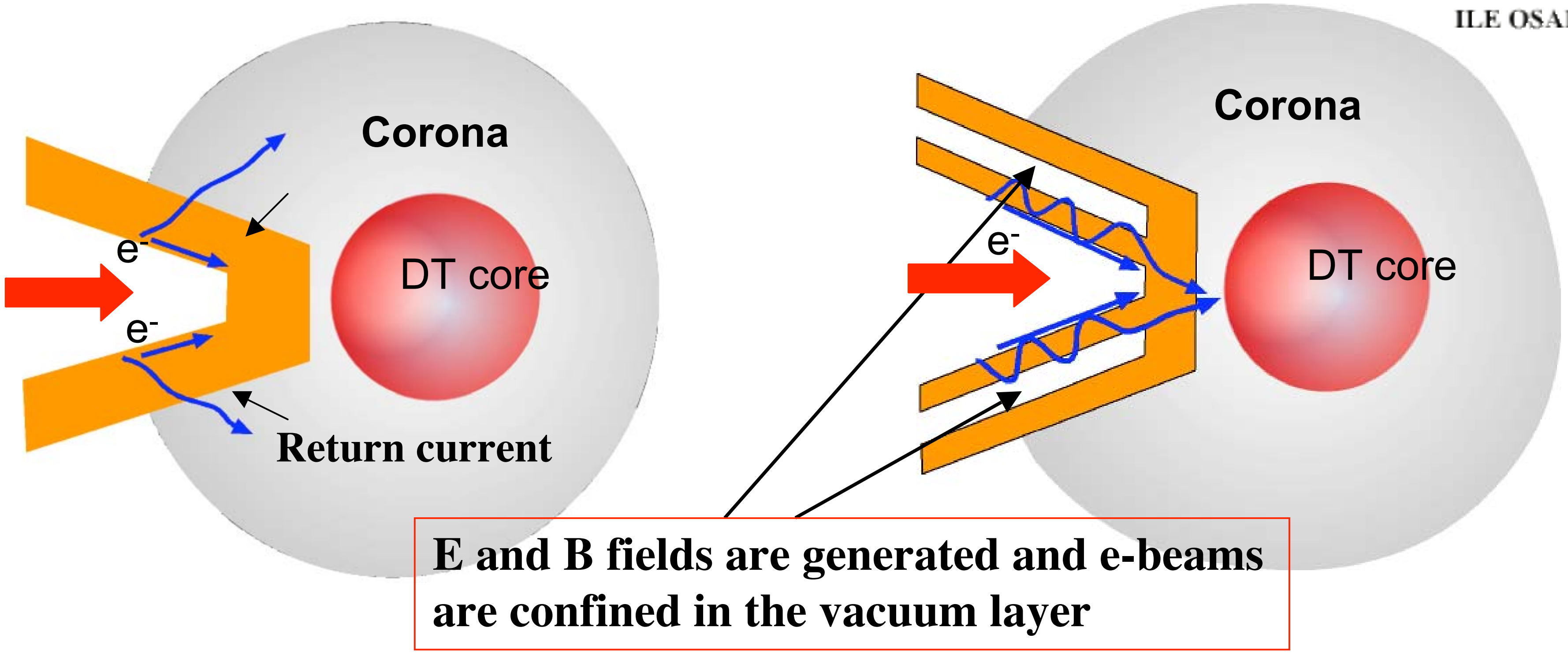

1. Single Cone target

2. Double-cone target

E-fields in the vacuum layer are disappearing in one pico second

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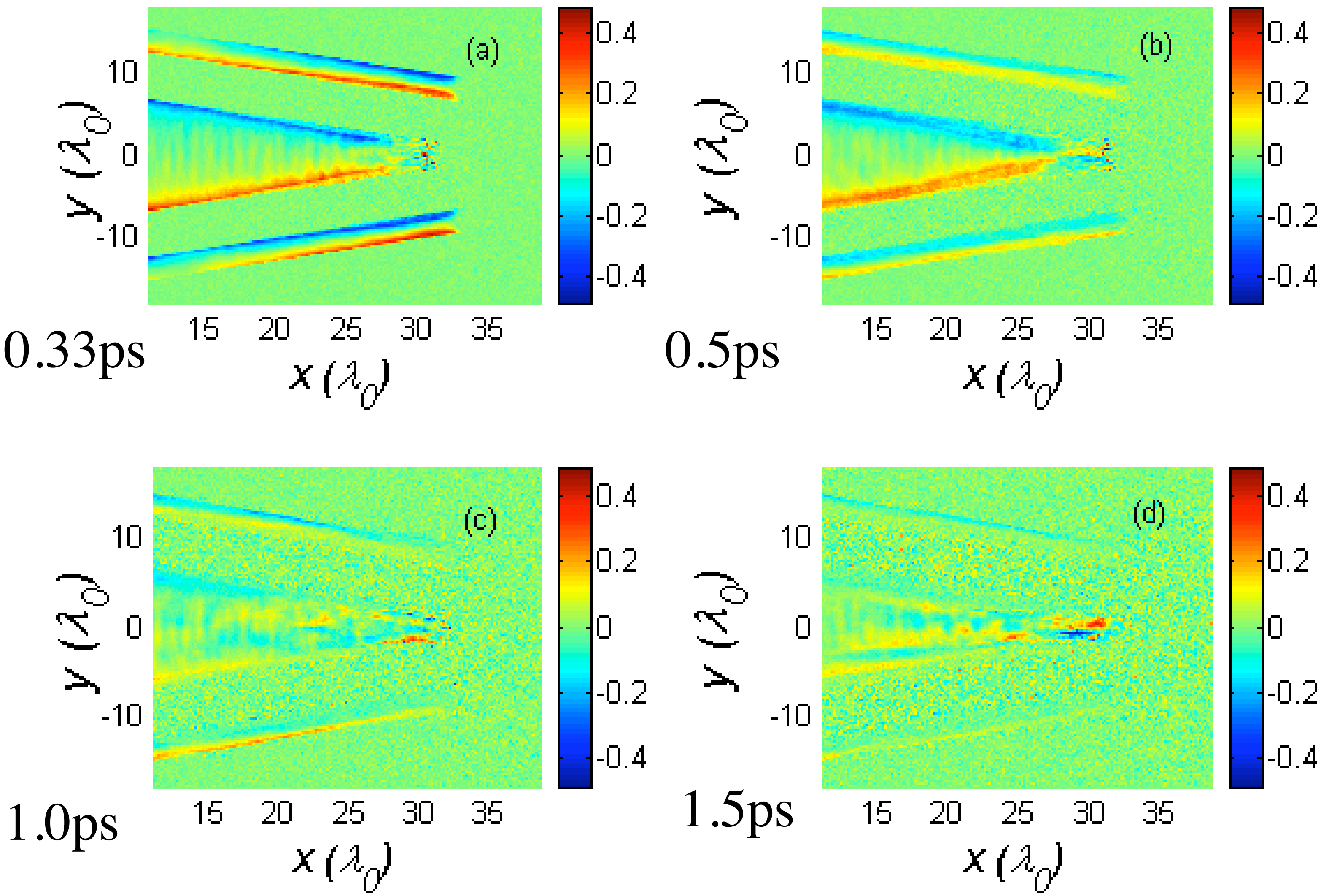

ion density profiles

-vacuum layers are filled with fast ions-

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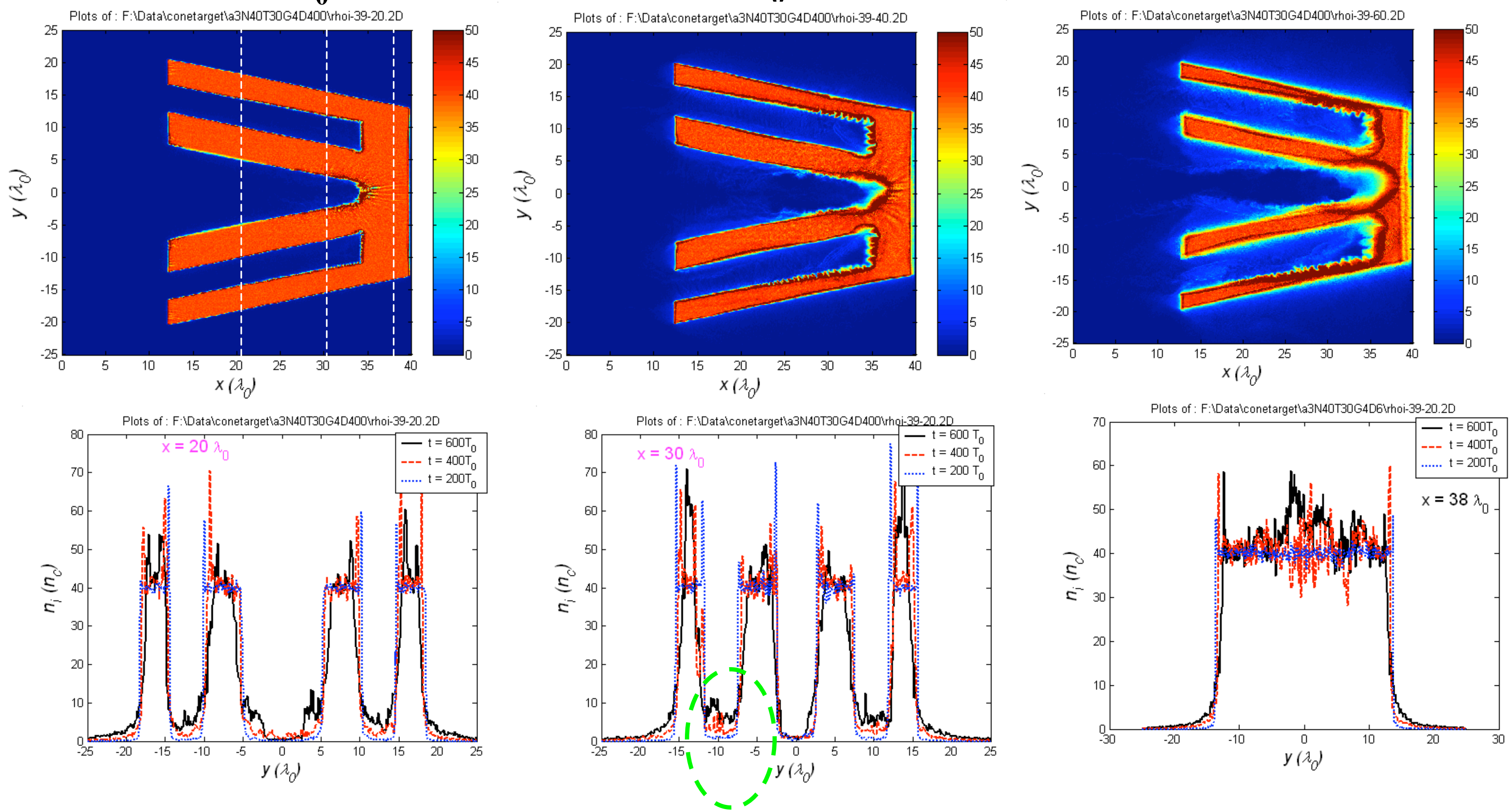
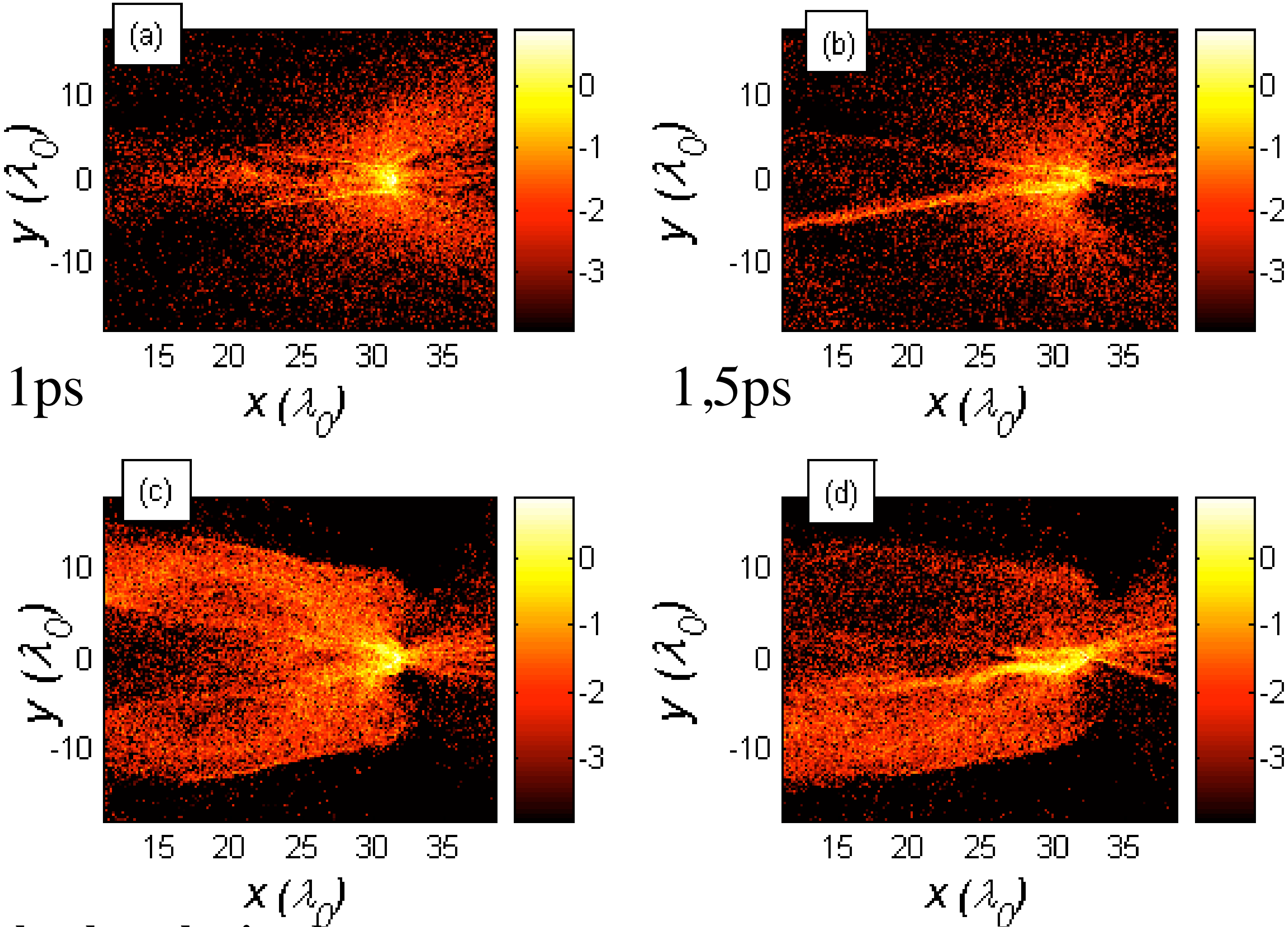
t = 200 T_0 | t = 400 T_0 | t = 600 T_0



Hot electron energy density for single cone and double cone

Single cone

Double cone



Hongbo Cai, etal to be submitted

B-fields are amplified for a long time
- seeded Weibel instabilitv-

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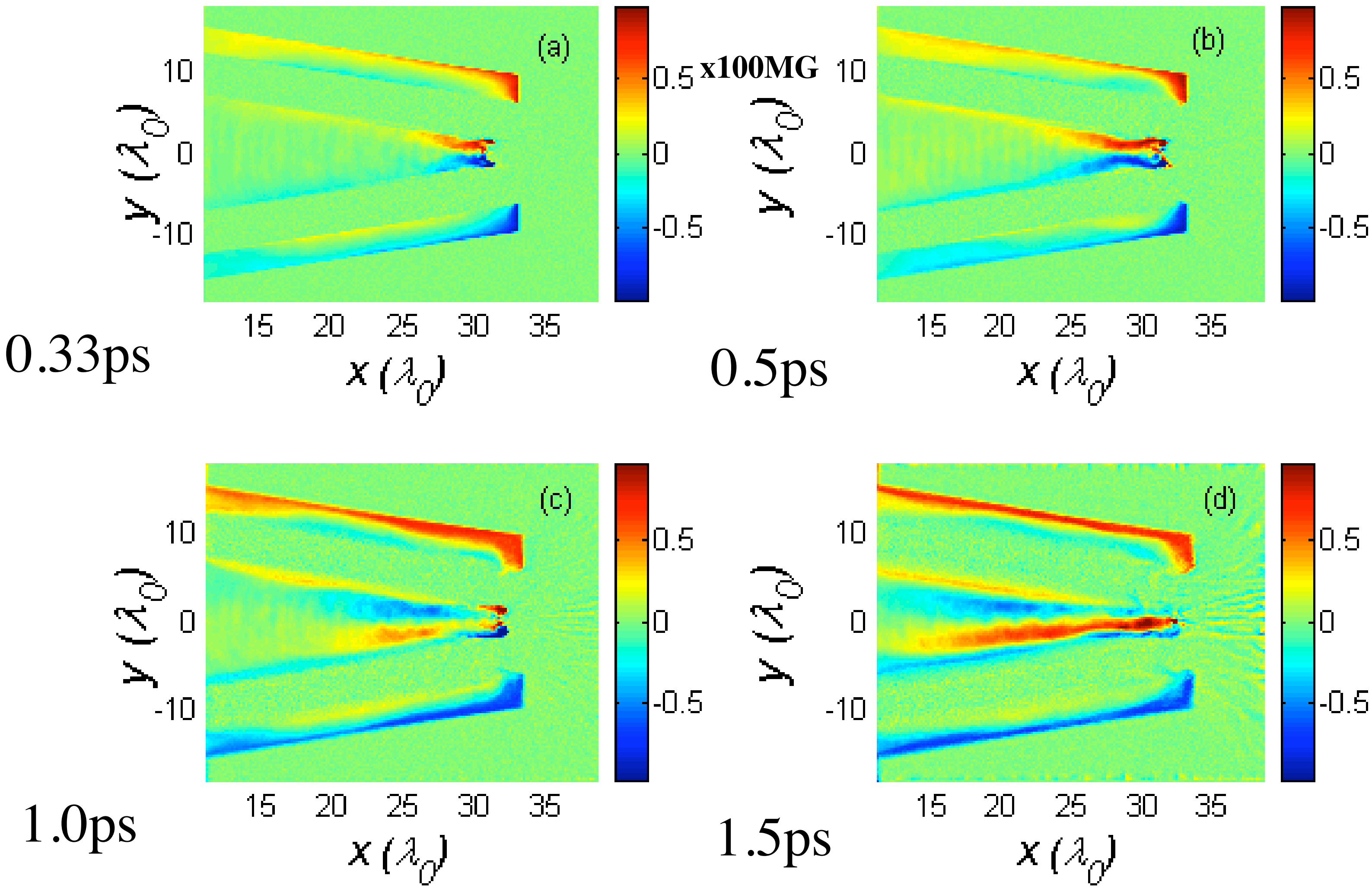
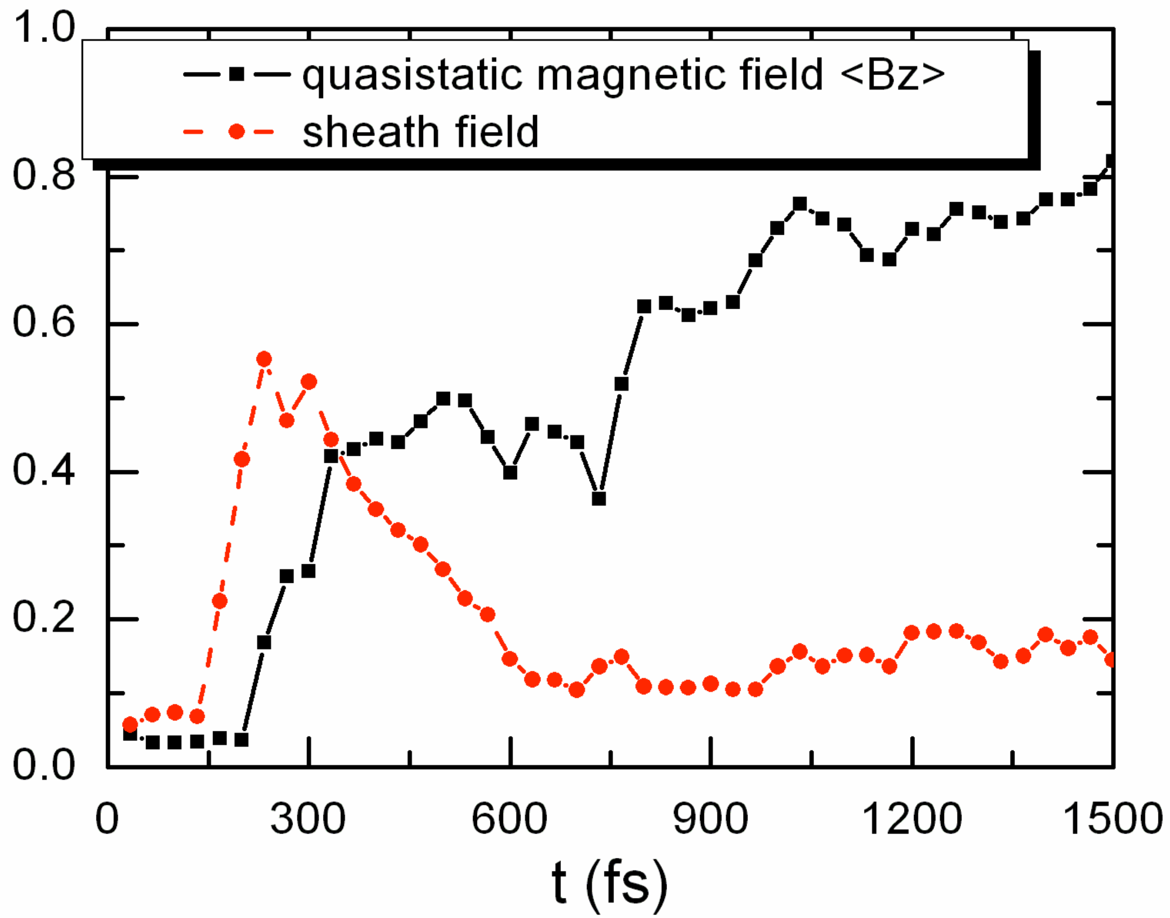


Temporal evolution of E-field and B-field



Advanced target for FIREX-I

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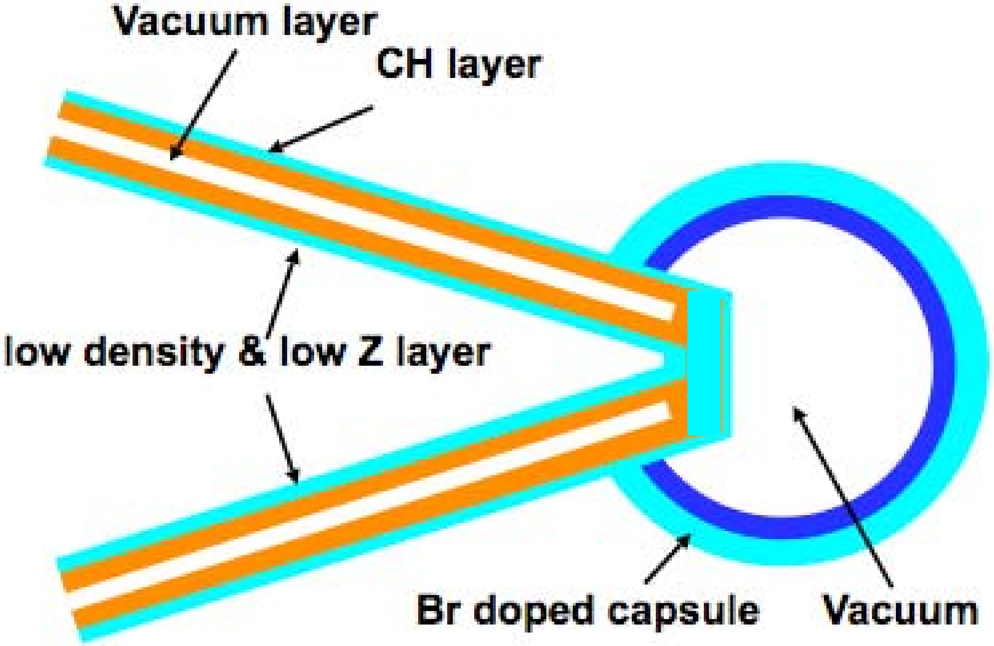
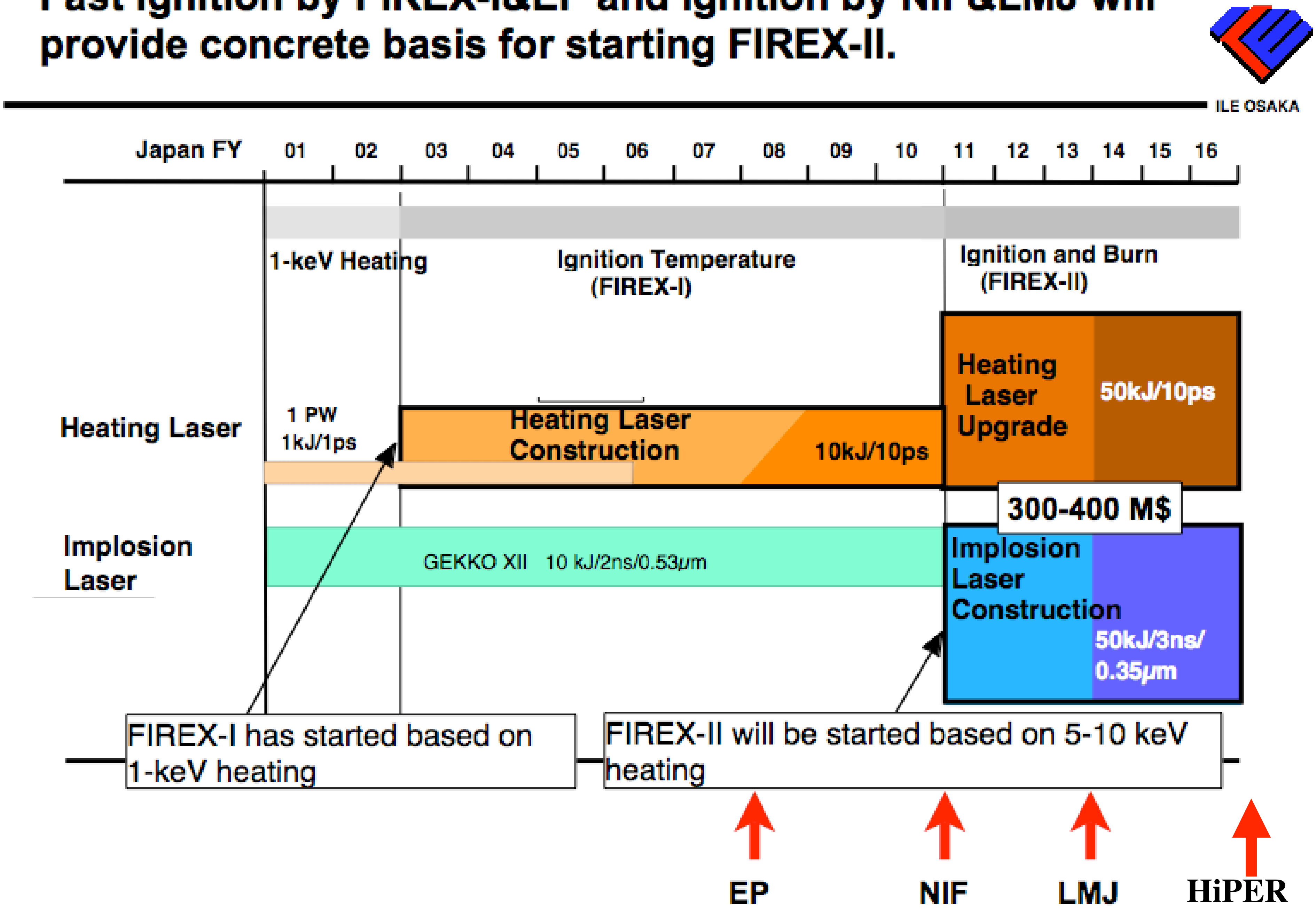
Inner foam –> Absorption
Double cone –> Ele. transport efficiency
Outer CH layer –> Expansion suppression
Br doped capsule –> Hydro stabilization
Vacuum center –> Jet mitigation



Evacuation requires solidification of hydrogen.

Fast ignition by FIREX-I&EP and ignition by NIF&LMJ will provide concrete basis for starting FIREX-II.



Summary

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- Osaka Univ. and NIFS are in collaboration with all Japan IFE community for FIREX project

- The 10kJ petawatt laser: LFEX is completed and will be commissioned and start experiments in Nov, 08 .
- Integrated fast ignition simulation code FI3 has been used for target design.
- A new target design concept are investigated for the coming FIREX-I experiments in 2009.