Status of Laser Fusion Research in Japan

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Fusion Power Associate'08 December 3, 2008, CA, USA

Outline

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- Introduction

1. FIREX project: LFEX laser

2. A New target design for fast ignition

3. Fusion neutron applications and future plan

- Summary

Fast Ignition opens a new rout to compact IF Reactor

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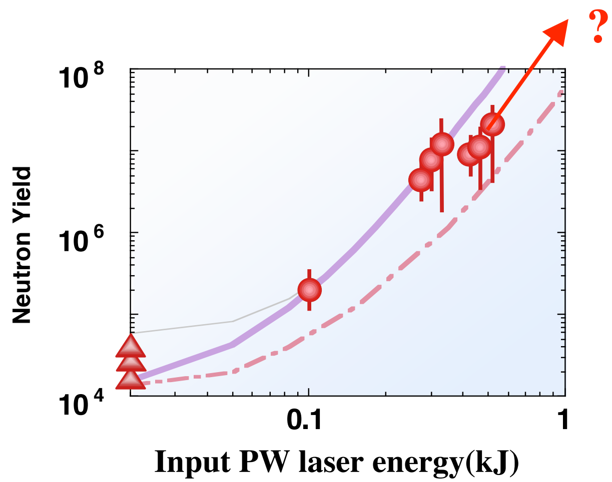
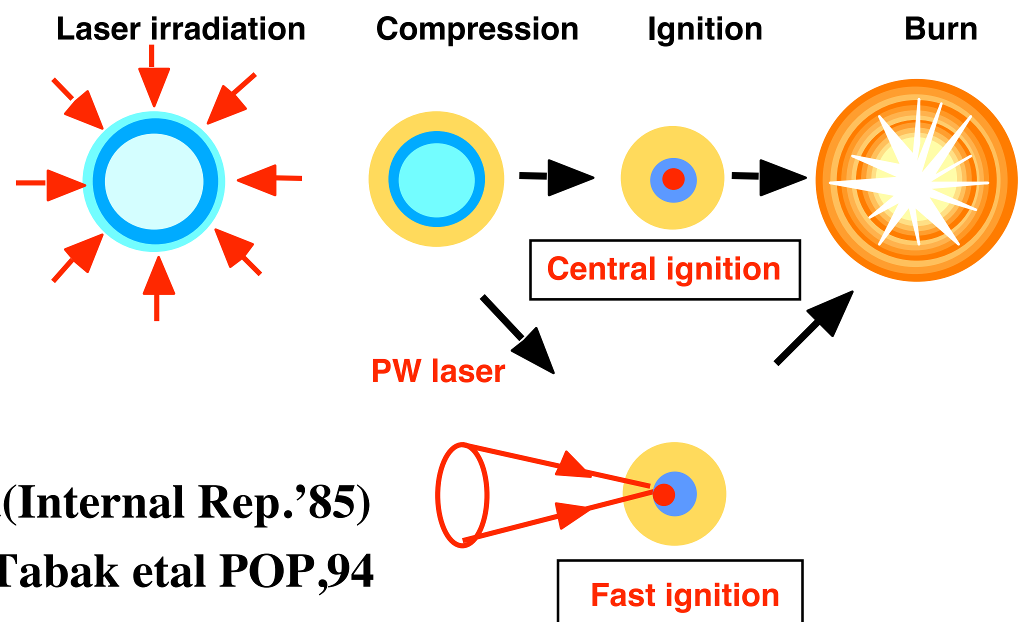


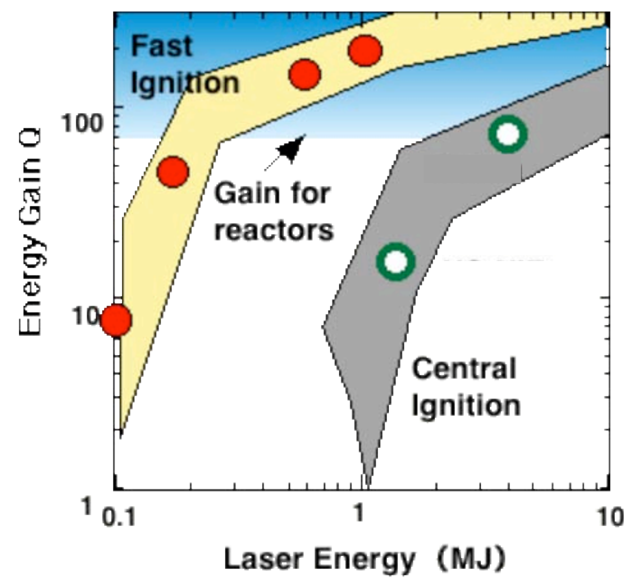


1985 Concept proposed by T.Yamanaka(Internal Rep.'85)

1994 N Basov, andM. Tabak etal POP,94

2002 1-keV heating by Cone target and PW laser

Japan-UK Joint Exp. : Kodama, etal Nature,02



GXII-LFEX (FIREX)

OMEGA-EP

Various ways for the fast heating of imploded plasma have been proposed

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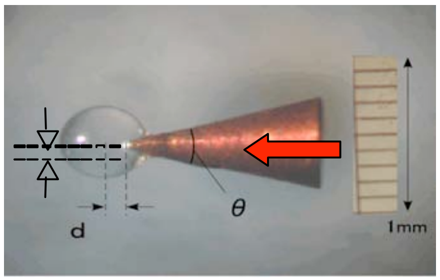
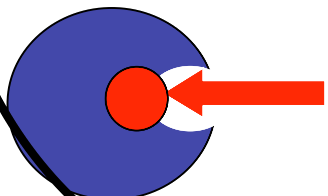
Electron heating



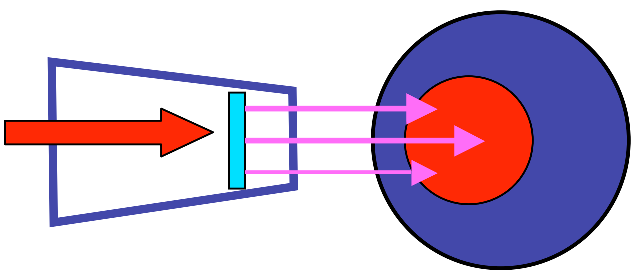
Cone guide



Hole boring

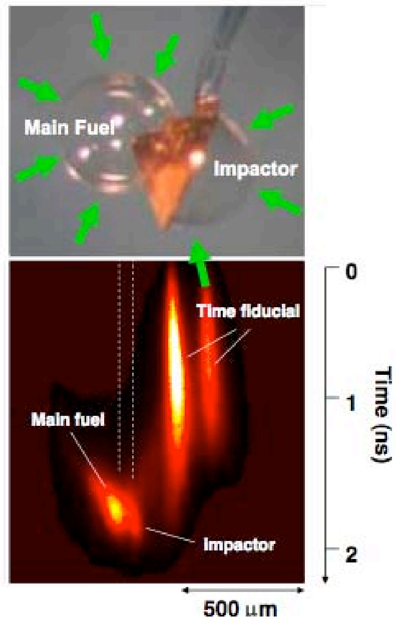
M.Tabak, etal
POP'94
R.Kodama, etal
Nature, '01, '02

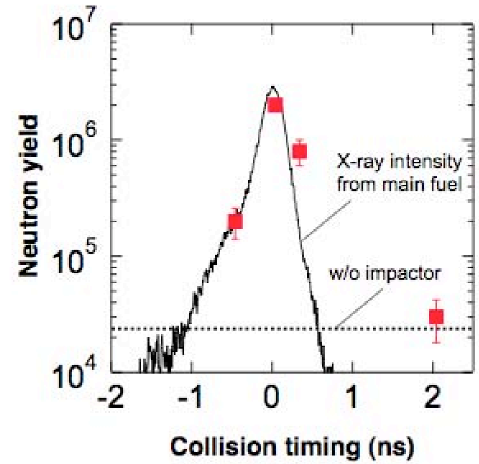
Ion heating



Super high velocity impact heating

H.Azechi etal
submitted to PRL, '08

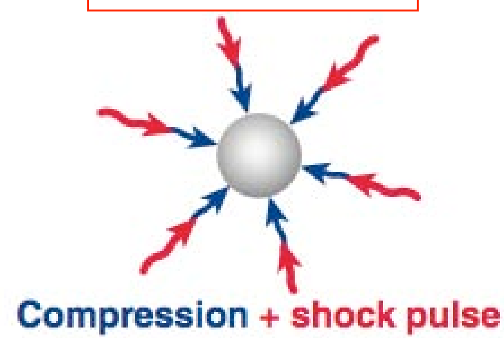




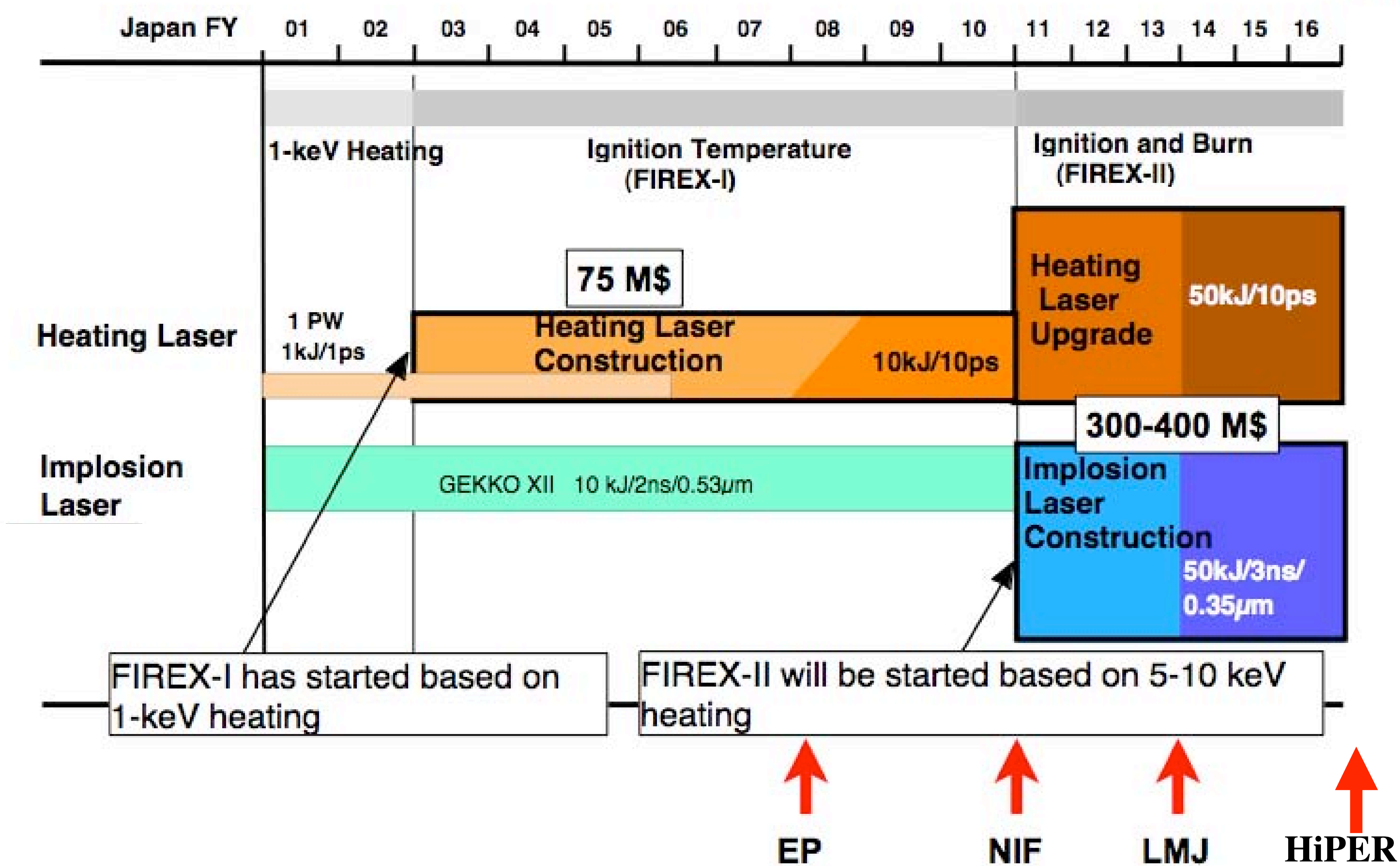
Neutron yield peaks at the collision timing.

R.Betti, PRL '07

Shock heating



Fast Ignition Equivalent Plasma Experiment will be done by FIREX-I and OMEGA-EP



Construction of LFEX (10kJ PW Laser)

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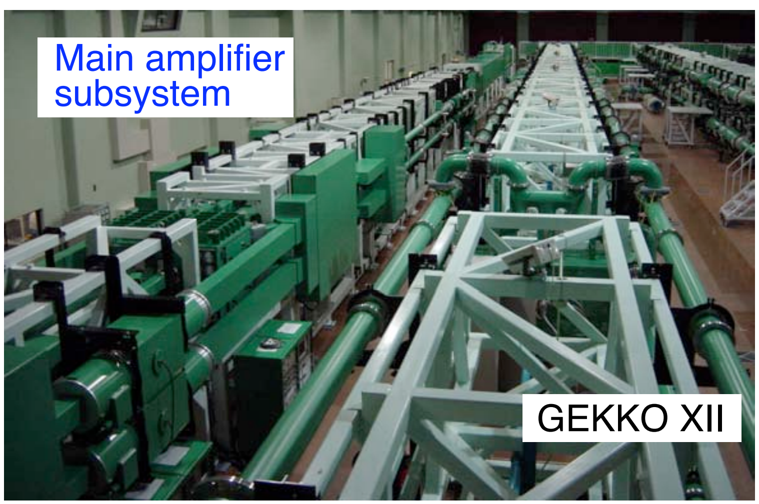
N. Miyanaga, H. Azechi, K. A. Tanaka[A], T. Kanabe[B], J. Kawanaka, Y. Fujimoto, K. Kondo[A], T. Jitsuno, H. Shiraga, K. Tsubakimoto, Y. Nakata, R. Kodama[A], H. Habara[A], K. Sueda, K. Yasukawa, J. Lu, G. Xu, N. Morio, S. Matsuo, S. Kitamura, K. Sawai, K. Suzuki, and K. Mima

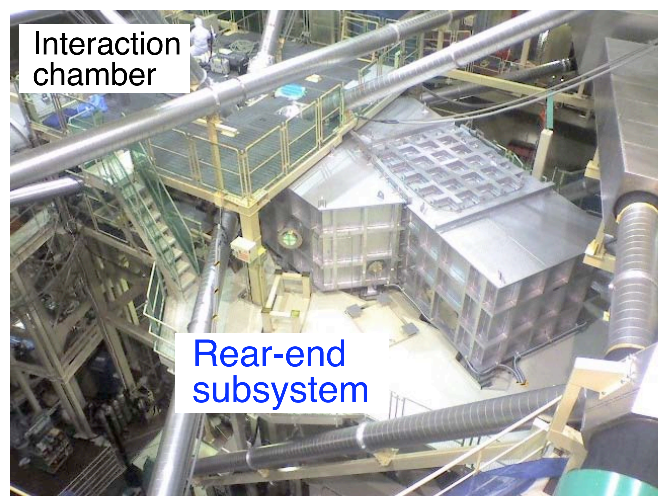
Institute of Laser Engineering, Osaka University

[A]*Graduate School of Engineering and Institute of Laser Engineering, Osaka University*

[B]*Graduate School of Engineering, University of Fukui, Fukui*

e-mail: miyanaga@ile.osaka-u.ac.jp





Construction schedule and summary

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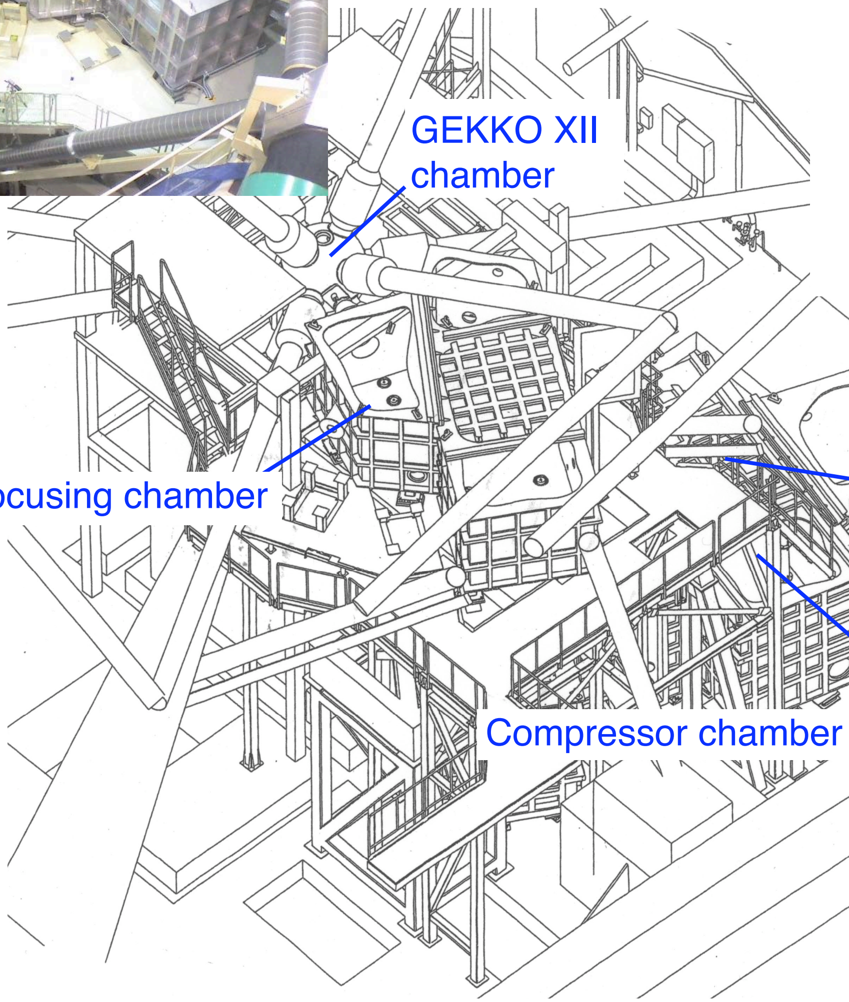
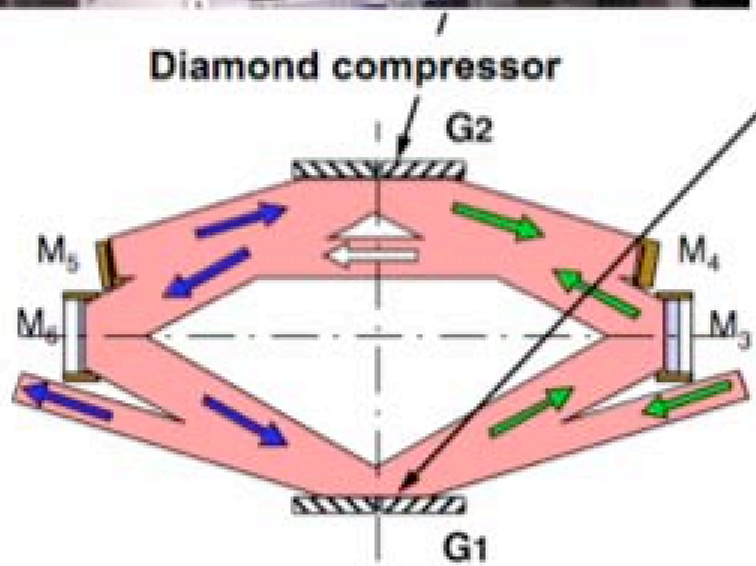
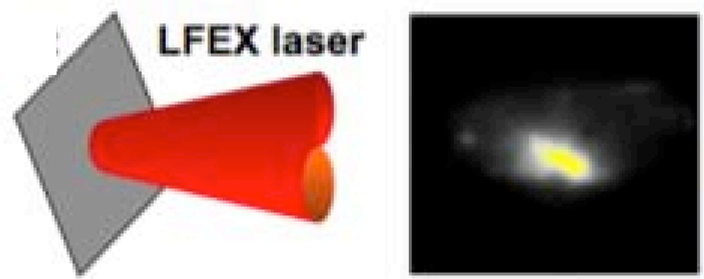
FY 2003
Construction started
FY 2007
Installed all commponents
FY 2008
Optimization of CPA / compression
1beam experiment
FY 2009
Completion of 4 beams
Full power integrated experiment



Present view of the installed gratings fabricated by PGL, MS., USA for LFEX



Focusing test: 40μm$^{\phi}$ spot of one beam



Target design with FI^3 simulation system

Fast Ignition Integrated Interconnecting code

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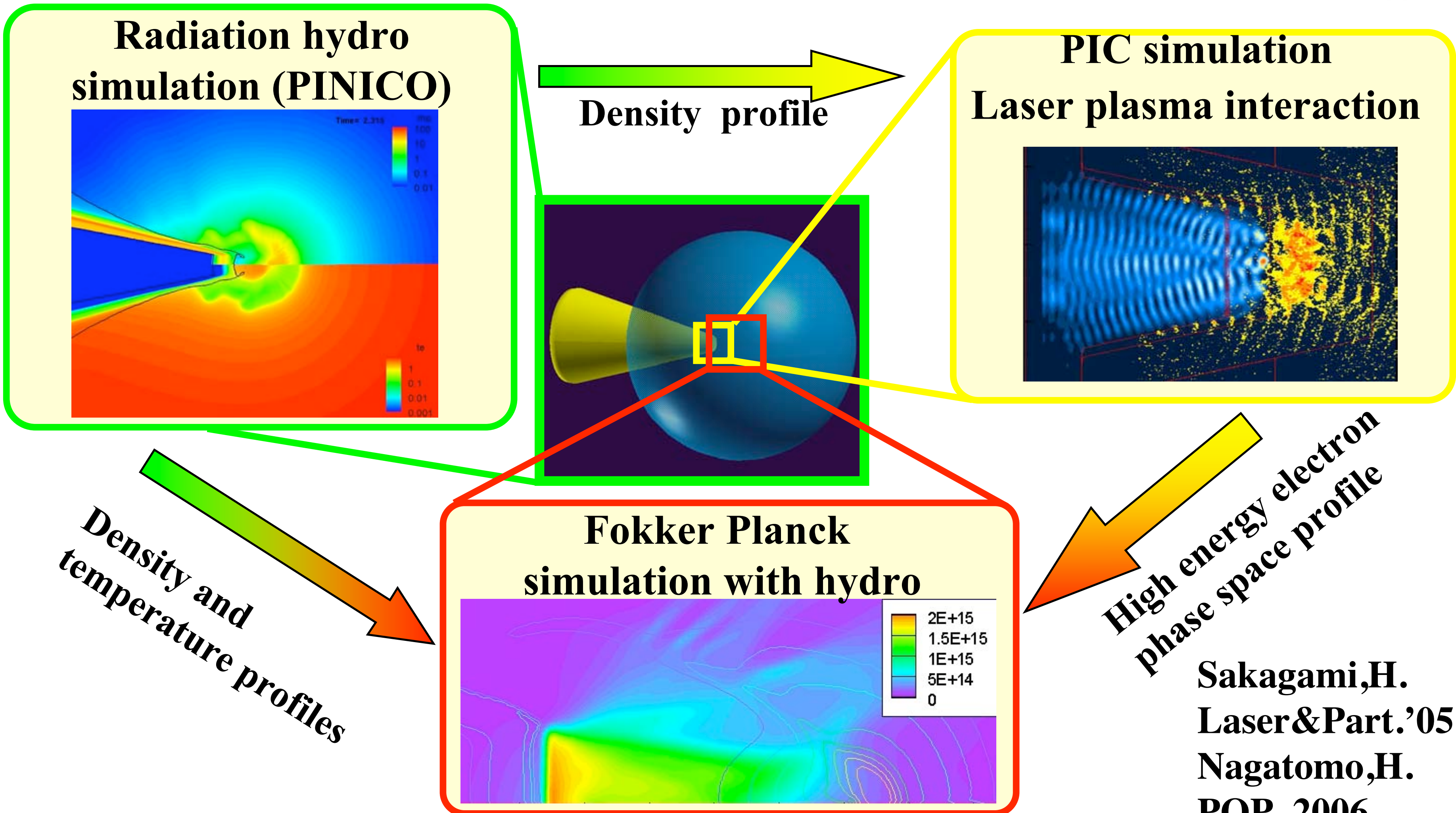

Sakagami,H. Laser&Part.'05
Nagatomo,H. POP, 2006

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

PINOCO 2-D Implosion Simulation of a Cone Shell Target
Plasma motion is compared with experiments

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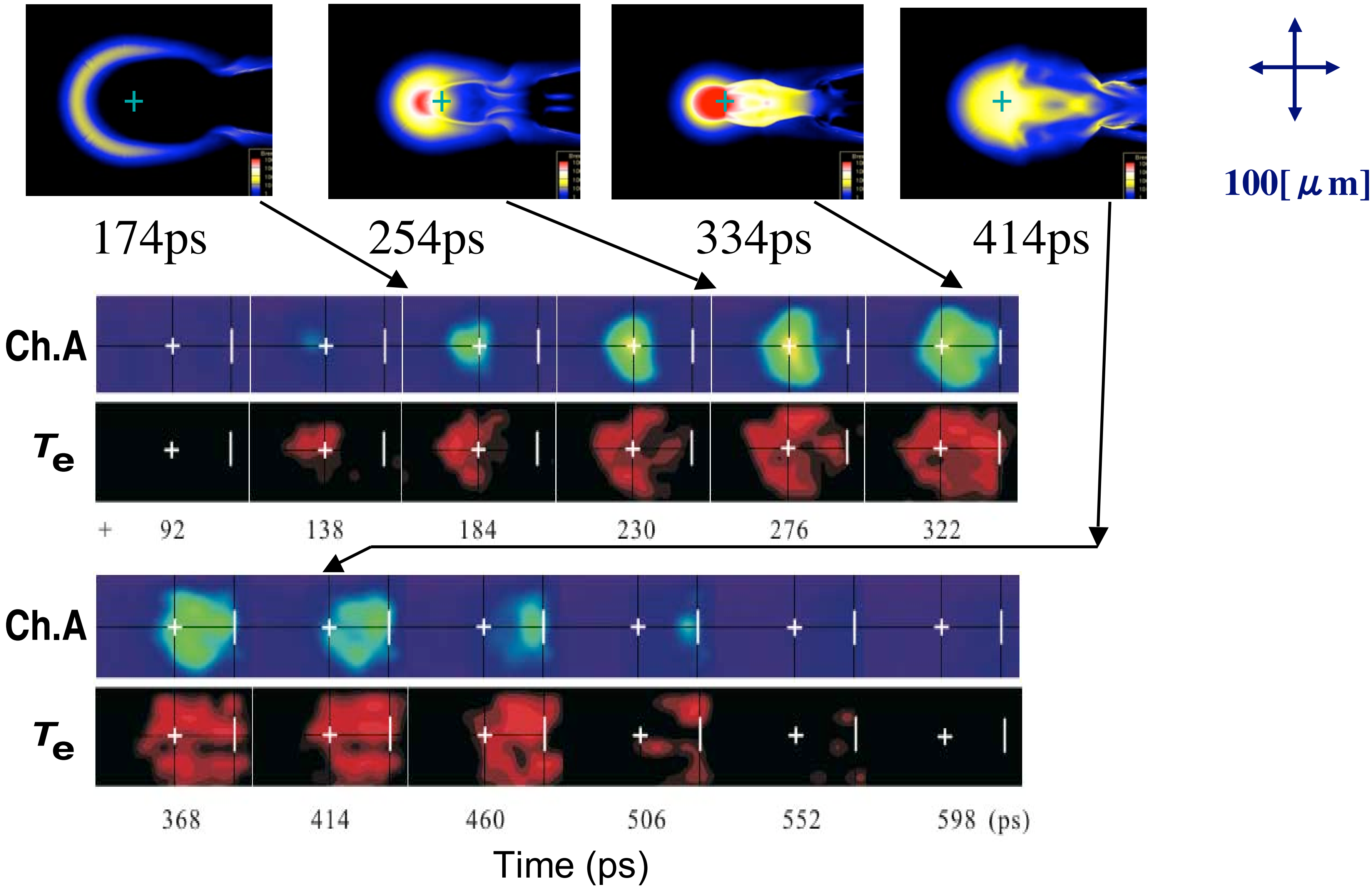

Design Parameter of the FIREX-I

Heating Requirement for CD plasma and DT plasma (cryogenic target)

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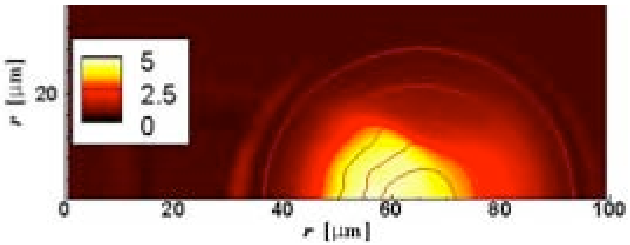
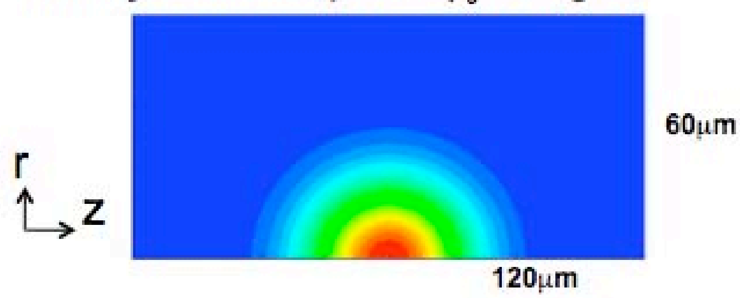
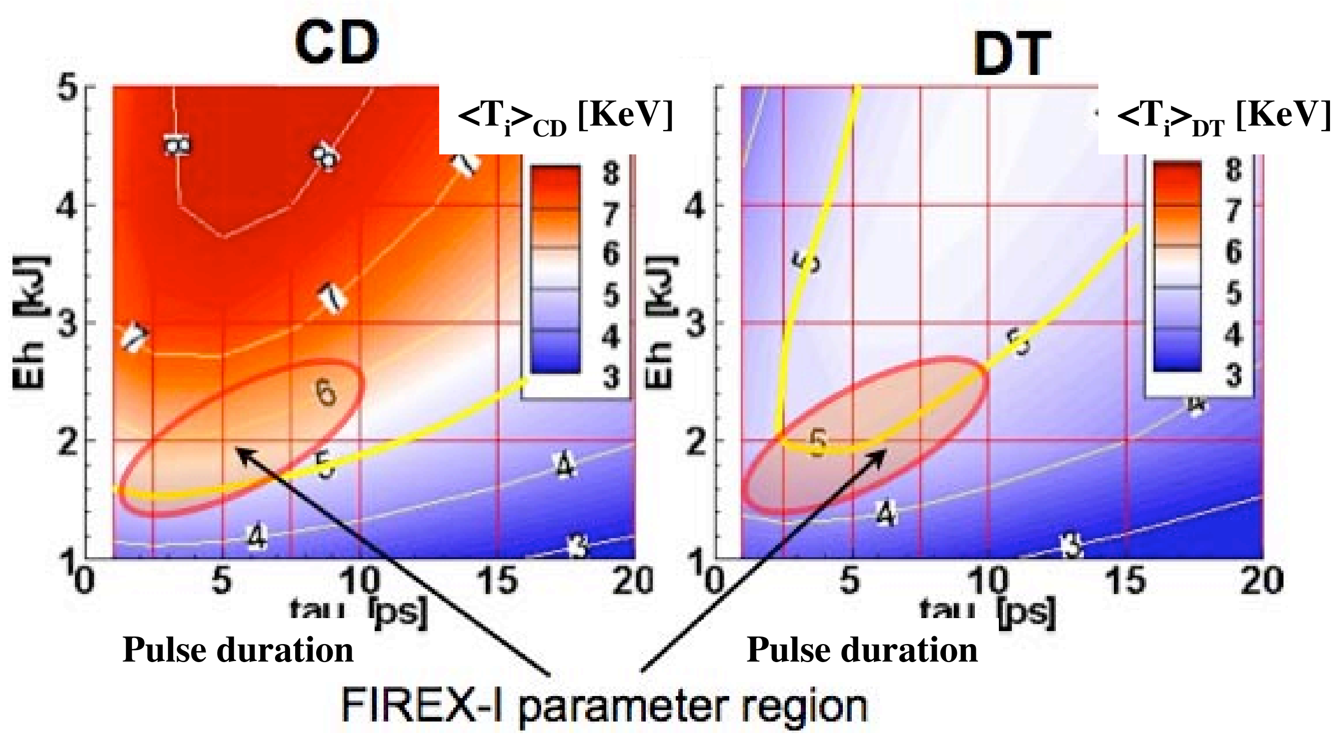


ρ_0 = 200g/cc, M_f = 2mg and ρR = 0.2g/cm^2

Density : Gaussian profile: ρ_0 = 200g/cc





High coupling efficiency from laser to core
(Relativistic electron generation and transport)

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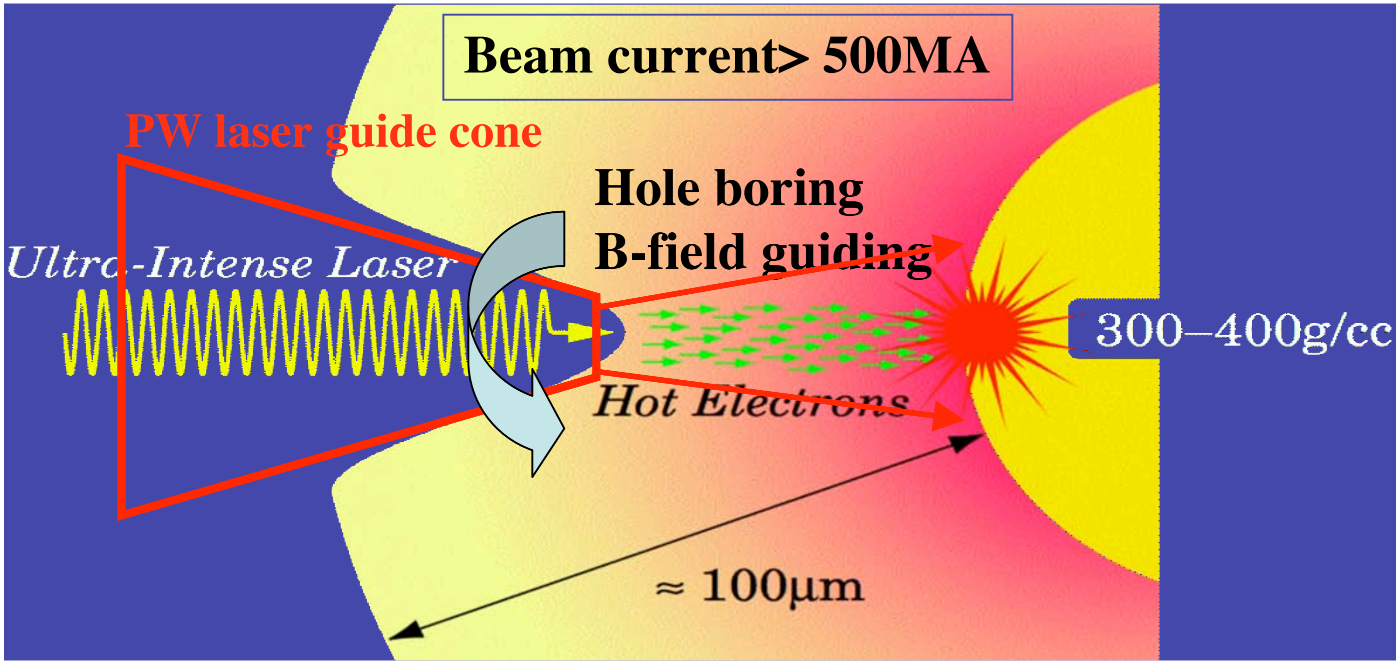
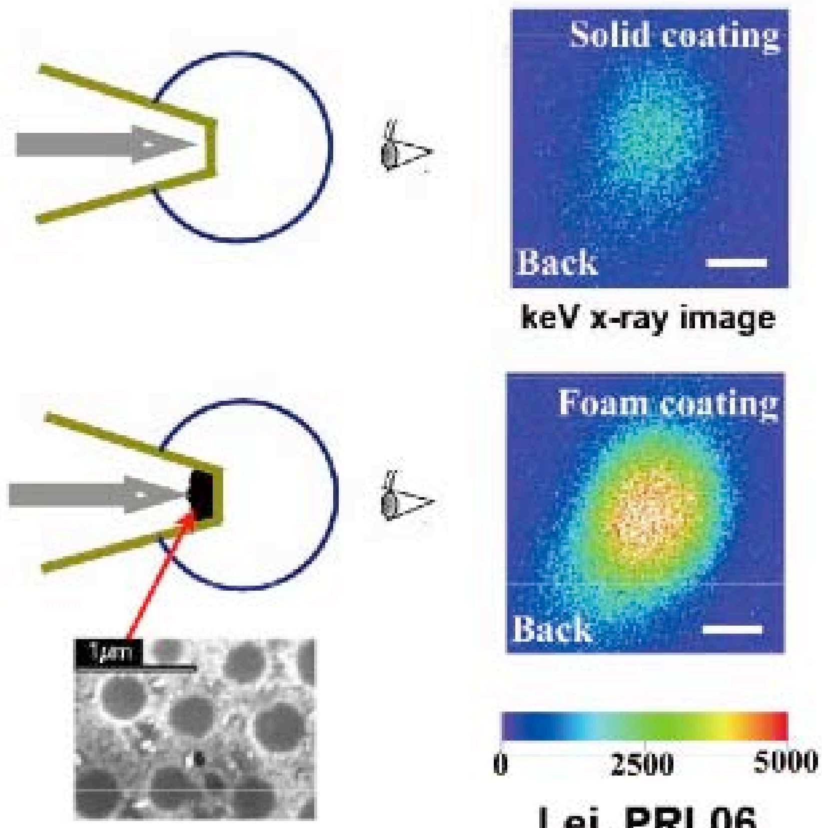
The coupling efficiency depends on REB temperature, transport,---

Laser intensity; $I_L = 2x10^{15}$ W/ πr_h^2 ~ 1~2x 10^{20} W/cm^2
Electron energy; $T_h = (\gamma\text{-}1)mc^2$,
$\gamma_p = [1+ I_L/(2.4x10^{18} W/cm^2)]^{1/2}$: T_h ~ 5 MeV
T_h -scaling: $T_h \sim \gamma_p (n_c/n_{UP})^{1/2} \sim I_L^{1/3}$ good news!, Beam transfer and divergence



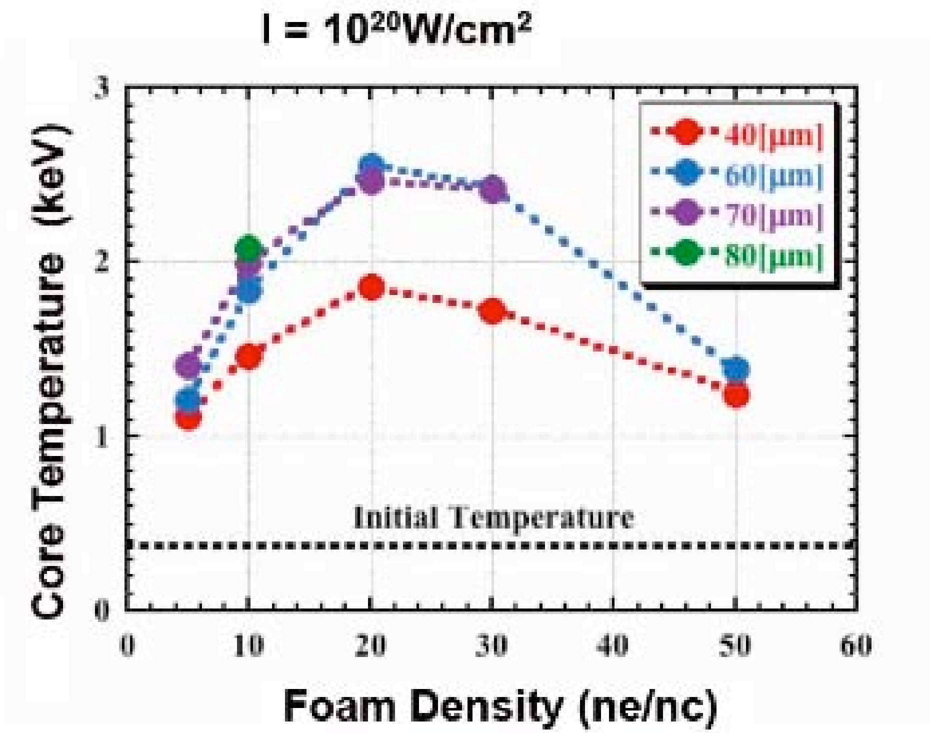
Control of Laser Plasma Interaction

Experimental test



Lei, PRL06

PIC + FP simulation



Too high T_{hot}

Too low abs.

Sakagami, IAEA08

High energy electrons can be confined to increase coupling efficiency

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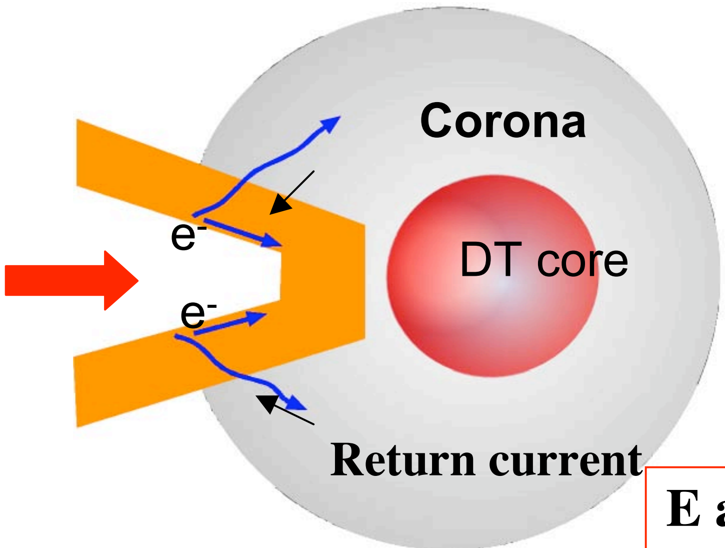
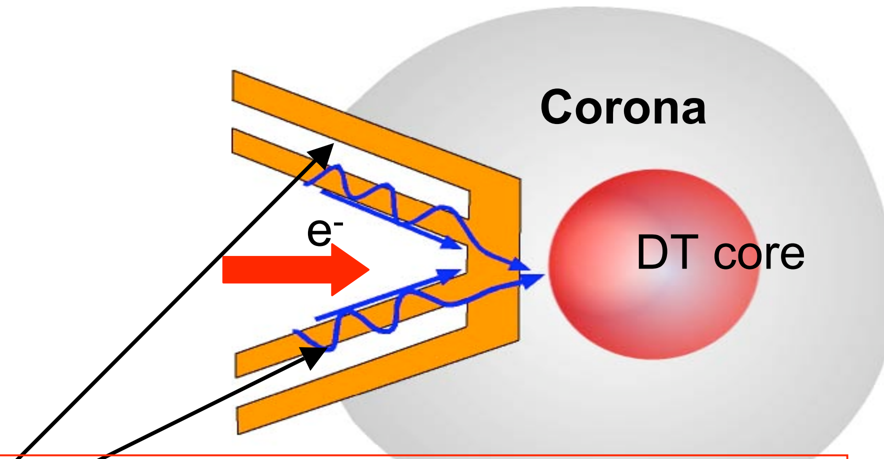
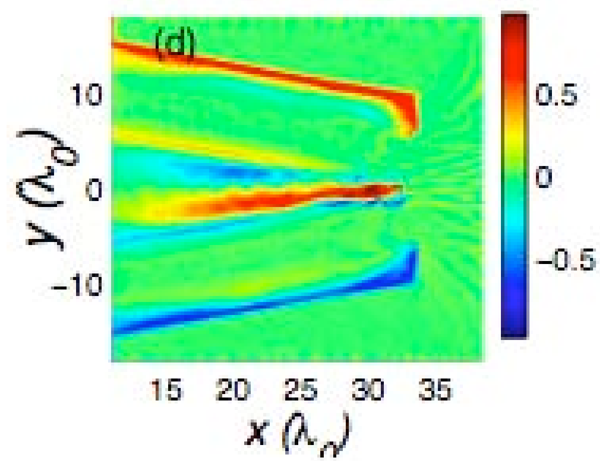
1. Single Cone target



2. Double-cone target



E and B fields are generated and e-beams are confined in the vacuum layer



High energy electron energy density in single cone and double cone

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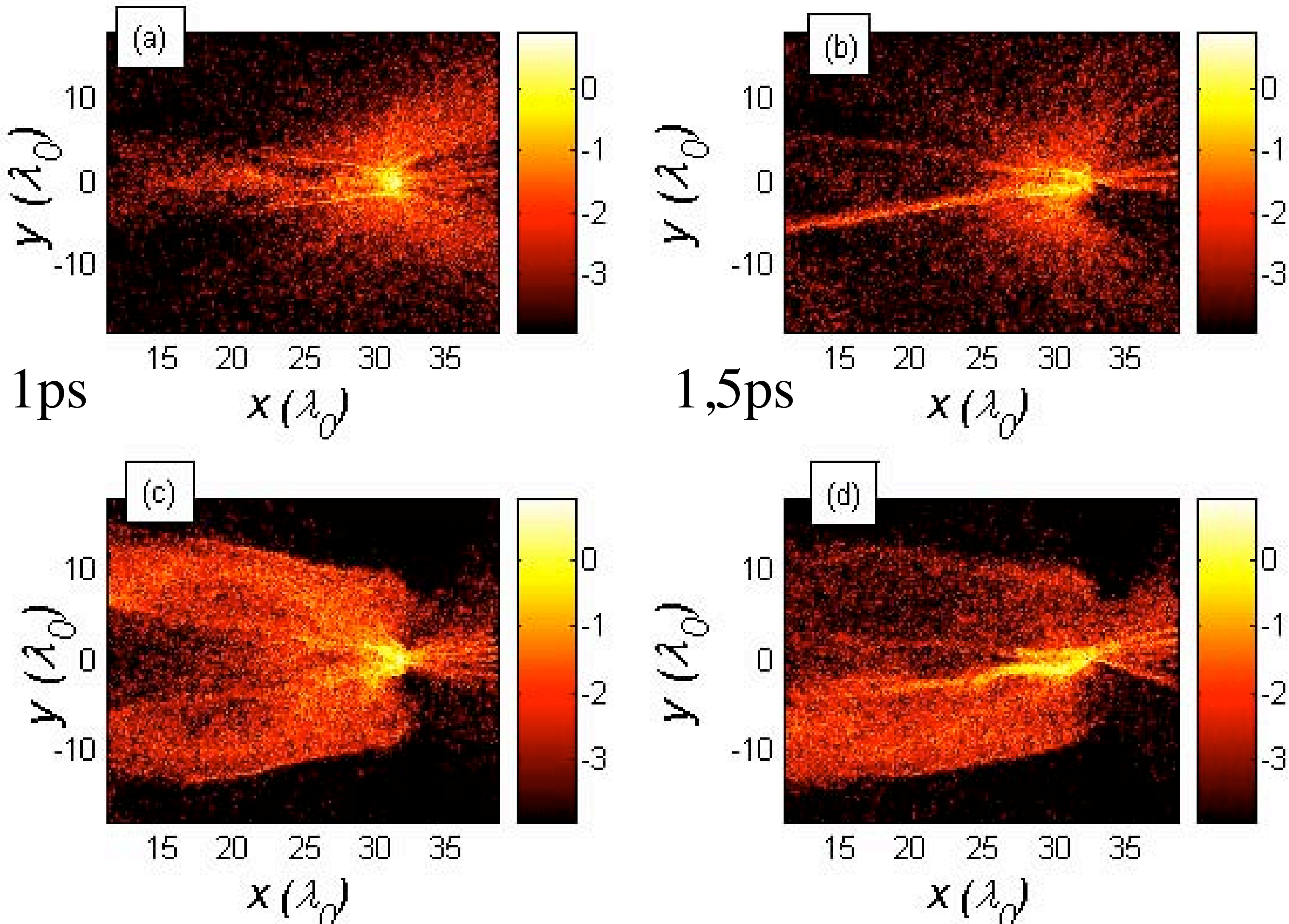
Single cone

Double cone



Hongbo Cai, etal to be submitted to PRL

Transfer efficiency to the cone tip

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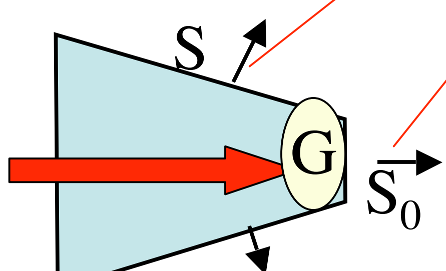
TABLE: Simulation energy flux normalized by the input laser power for single cone and double cone.

	cone tip		side wall	backward
	(-18, 18) λ	(-8, 8) λ		
Single	31.4	18.6	23.9	0.41
Double	38.4	28.6	8.9	0.41

$$dQ_h/dt = G - Q_h(cS/3V)(1-\beta) - Q_h(cS_0/3V)$$

source side wall loss forward emission

Q_h : stored energy



$$Q_h = G/((cS/3V)(1-\beta) + (cS_0/3V))$$

When β approach 1, $Q_h(cS_0/3V) = G$

Advanced target for FIREX-I

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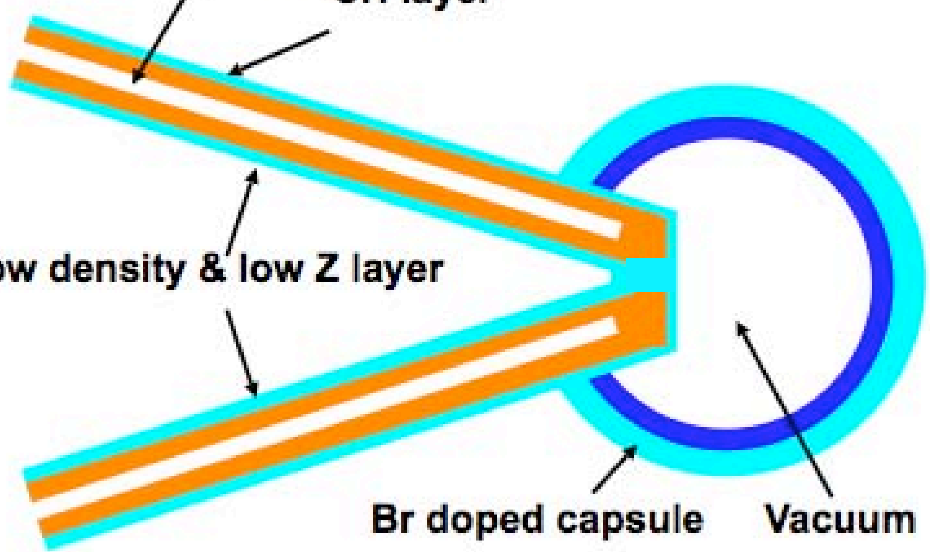
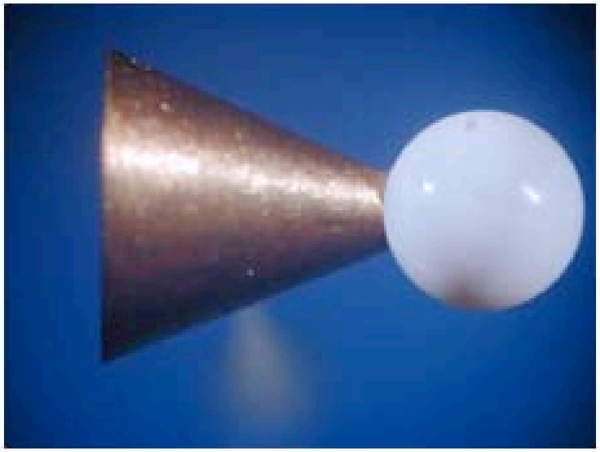
Inner foam –> Absorption
Double cone –> Ele. transport efficiency
Outer CH layer –> Expansion suppression
Br doped capsule –> Hydro stabilization
Vacuum center –> Jet mitigation





Evacuation requires solidification of hydrogen.

IFE Forum, Osaka Univ. and GPI Joint Committee on Laser Neutron Applications (since Jan. 2008)

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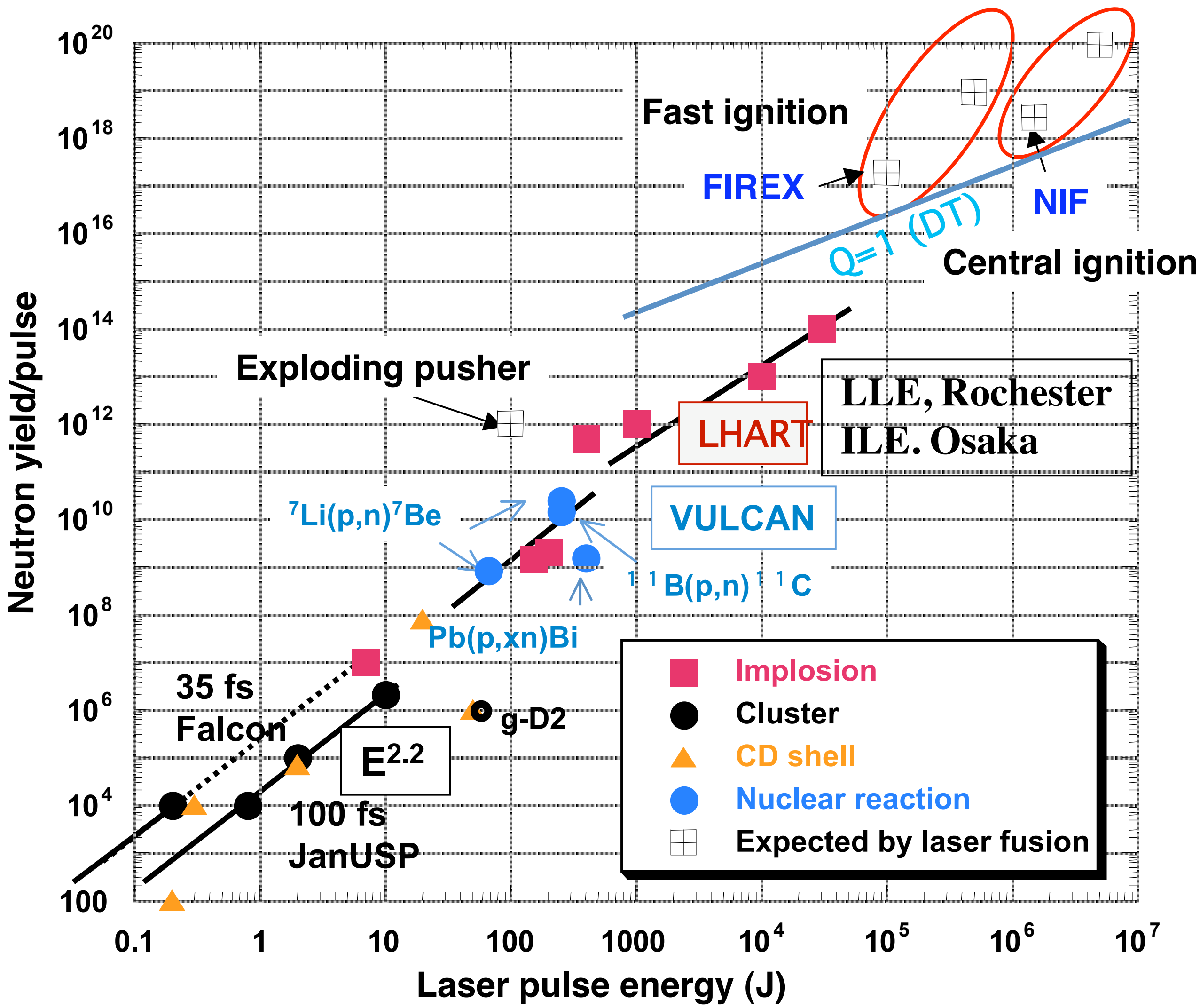


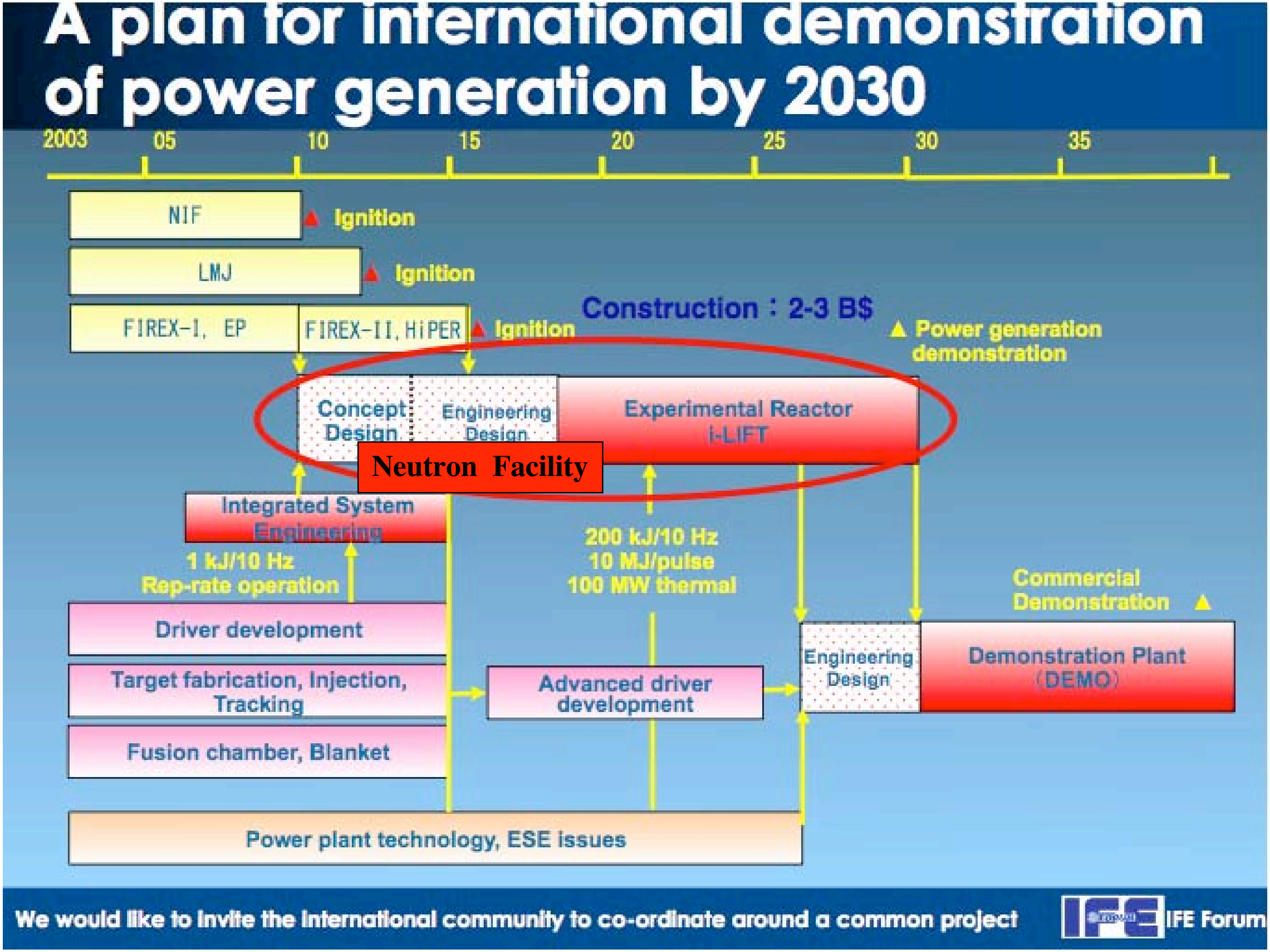
After S.Nakai

10^{11} ~10^{12} n/sec
Imaging,
Diagnostics, etc
[hydrogen image]

10^{12}~10^{13} n/sec
Cancer therapy
[BNT]

10^{13}~10^{14} n/sec
Semiconductor
Processing
[P doping in Si]

>10^{15}n/sec
Fission Fuel Waste
Burning
[LIFE]


A plan for international demonstration of power generation by 2030
2003
05
10
15
20
25
30
35
NIF
Ignition
LMJ
Ignition
FIREX-I, EP
FIREX-II, HiPER
Ignition
Construction : 2-3 B$
Power generation demonstration
Concept Design
Engineering Design
Experimental Reactor
i-LIFT
Neutron Facility
Integrated System Engineering
1 kJ/10 Hz
Rep-rate operation
200 kJ/10 Hz
10 MJ/pulse
100 MW thermal
Commercial Demonstration
Driver development
Target fabrication, Injection, Tracking
Fusion chamber, Blanket
Advanced driver development
Engineering Design
Demonstration Plant
(DEMO)
Power plant technology, ESE issues
We would like to invite the international community to co-ordinate around a common project
IFE Forum

Summary

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- Osaka University and NIFS are in collaboration for FIREX project in target fabrication, simulation, and experiment.

- The 10kJ petawatt laser: LFEX is completed and one beam experiment starts in Dec. 08 .

- Integrated fast ignition simulation code FI3 has been applied to the FIREX target design.

- A new target design concept are investigated for the coming FIREX-I experiments in 2009.

- Applications of laser fusion neutron for science and industry are explored.

Broad-band (CPA) activation test of main amplifier

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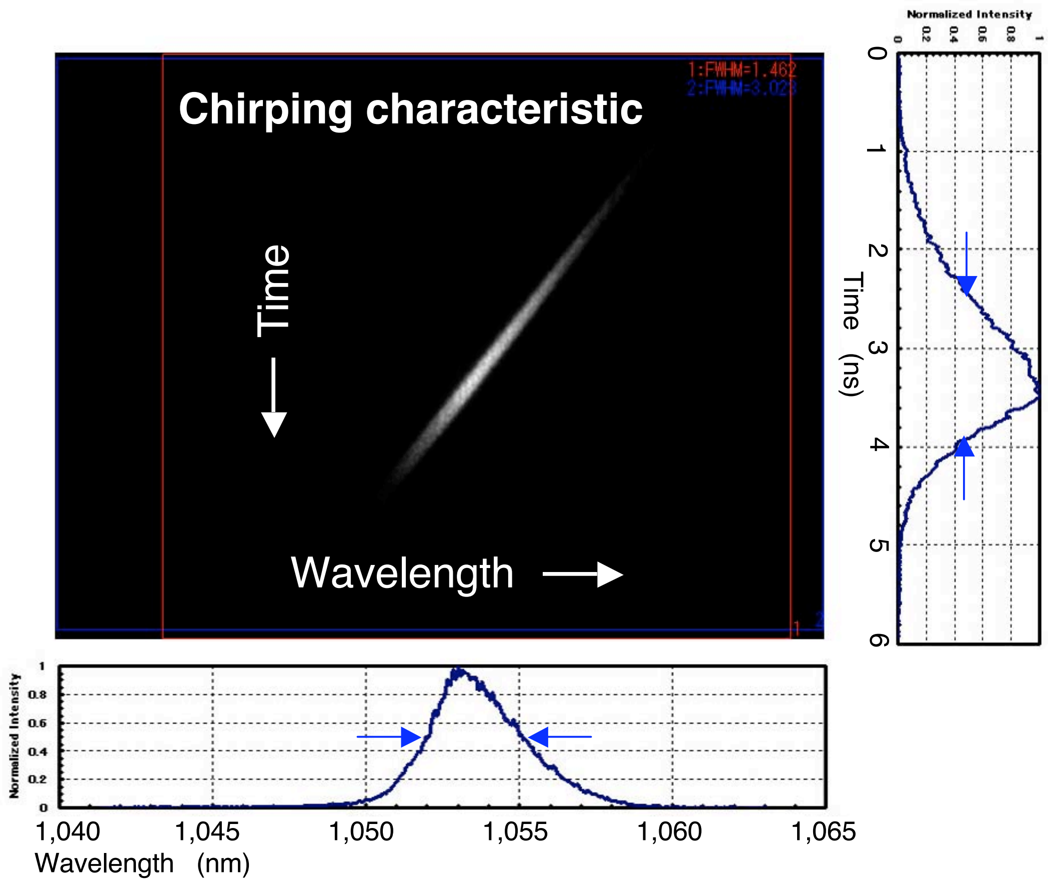

Spectral width: 3.1 nm

Pulse width: 1.45 ns

(to be extended to 2.2ns)

Beam energy

2.3 kJ/ 37x37cm^2

Final test will start soon aiming at 12kJ/4 beams.