Fast Ignition crucial issues that could be investigated on OMEGA

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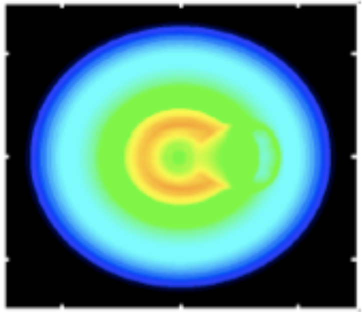
Summary

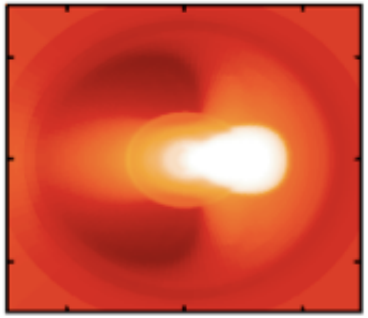
- Baseline target for the HiPER project
- crucial issues for particular design and for F.I.
- previous experiments addressing those issues
- new experimental opportunities at OMEGA
- framework for future collaborations

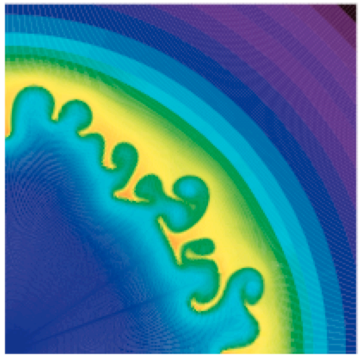
Tools

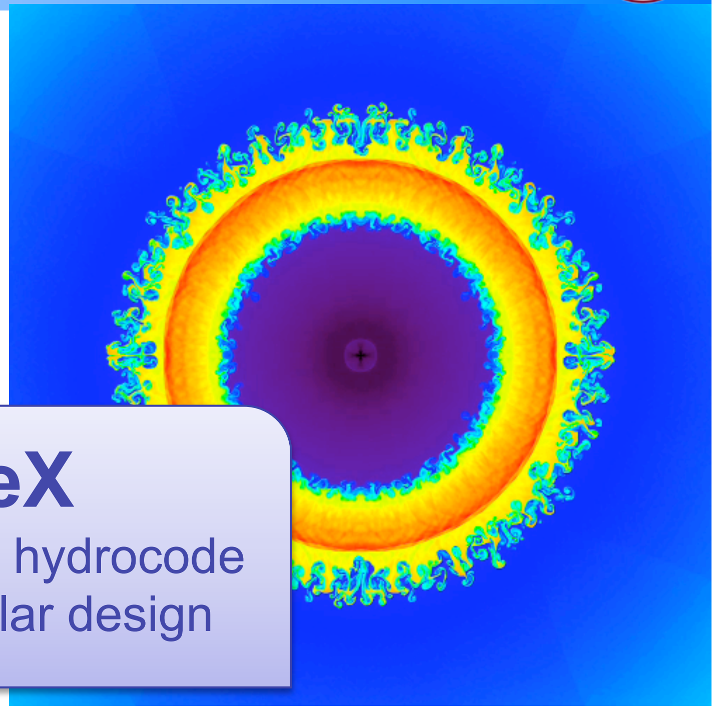
DUED

2D lagrangian hydrocode with real matter EOS, laser raytracing, nuclear burn, radiative transport, alpha particle diffusion, ebeam MC energy deposition







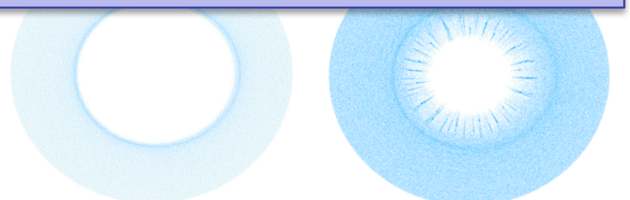


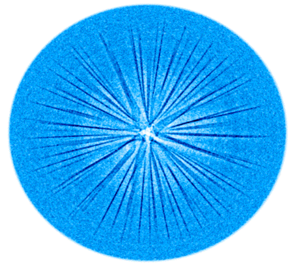
FleX

3D Eulerian hydrocode with modular design

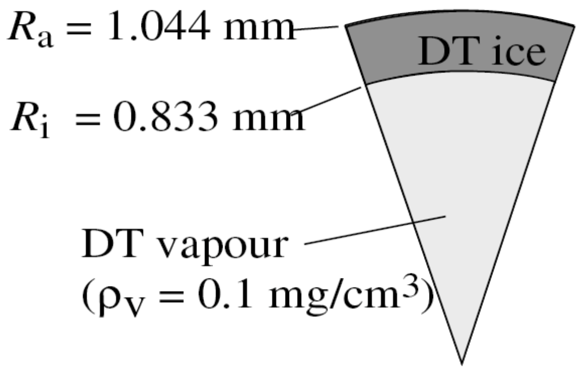
PTRACE

3D charged particle tracer
user-prescribed e.m. fields
energy deposition in stack detectors



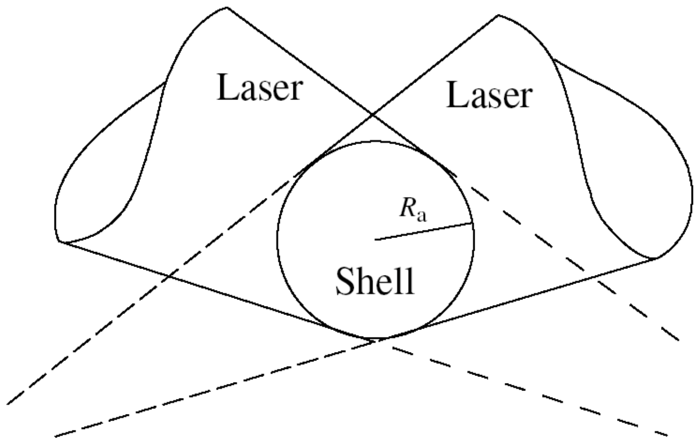


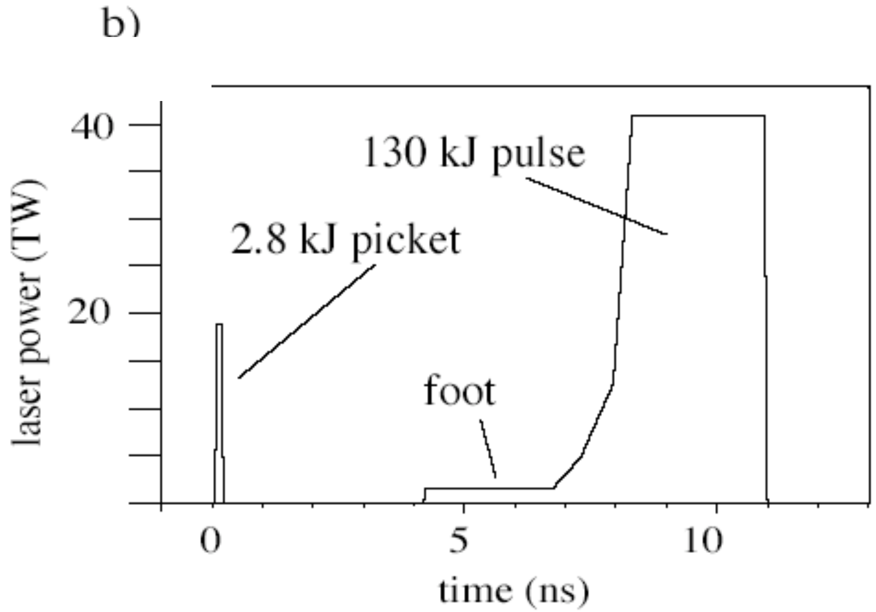
Baseline target



compression laser pulse
- wavelength = 0.35 μm
- focussing optics f/18
- energy = 130-250 kJ

- absorbed energy = 90 kJ





ref: S. Atzeni, A. Schiavi and C. Bellei, *Phys. Plasmas*, **15**, 14052702 (2007)

Which Goal?

1.a) Ignition at minimal energy (the initial HiPER goal)

1.b) Ignition at low risk

2) High-rep. rate test facility (burst mode)

3) Prototype of a preliminary demo reactor (?!?)

what is crucial and mission critical really depends on the final goal of the proposed facility

this will be clear at the end of the preparatory phase only

The rationale behind the design

maximize energy gain while keeping risks “small” (?)

==>

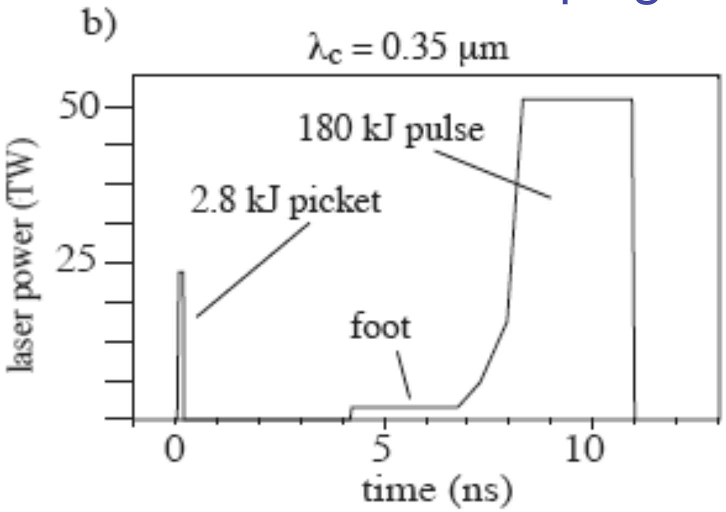
- minimize compression energy (keep entropy low)
- ignite at “minimum energy”

at the same time

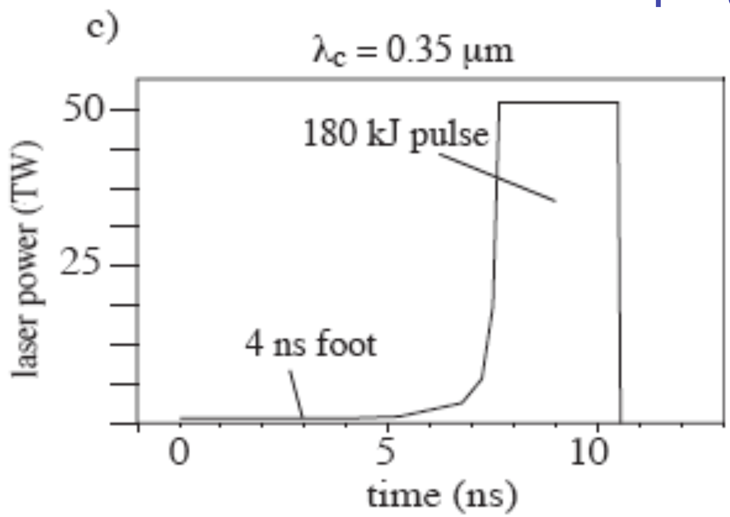
- make sure RTI growth is small
- keep LPI small
- try to leave safety margins

Compression pulse

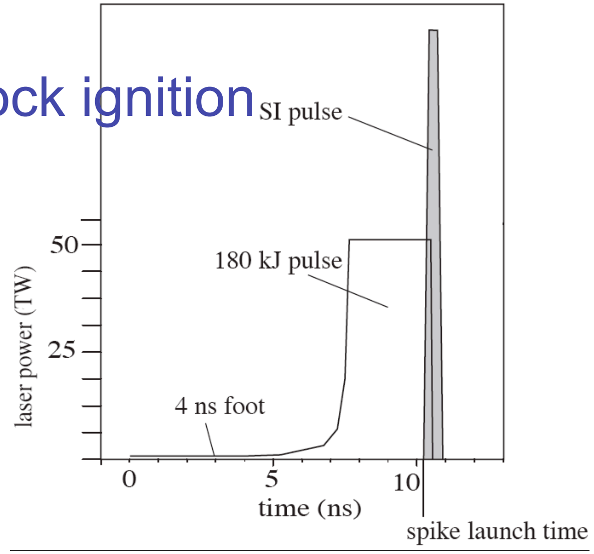
with adiabat shaping



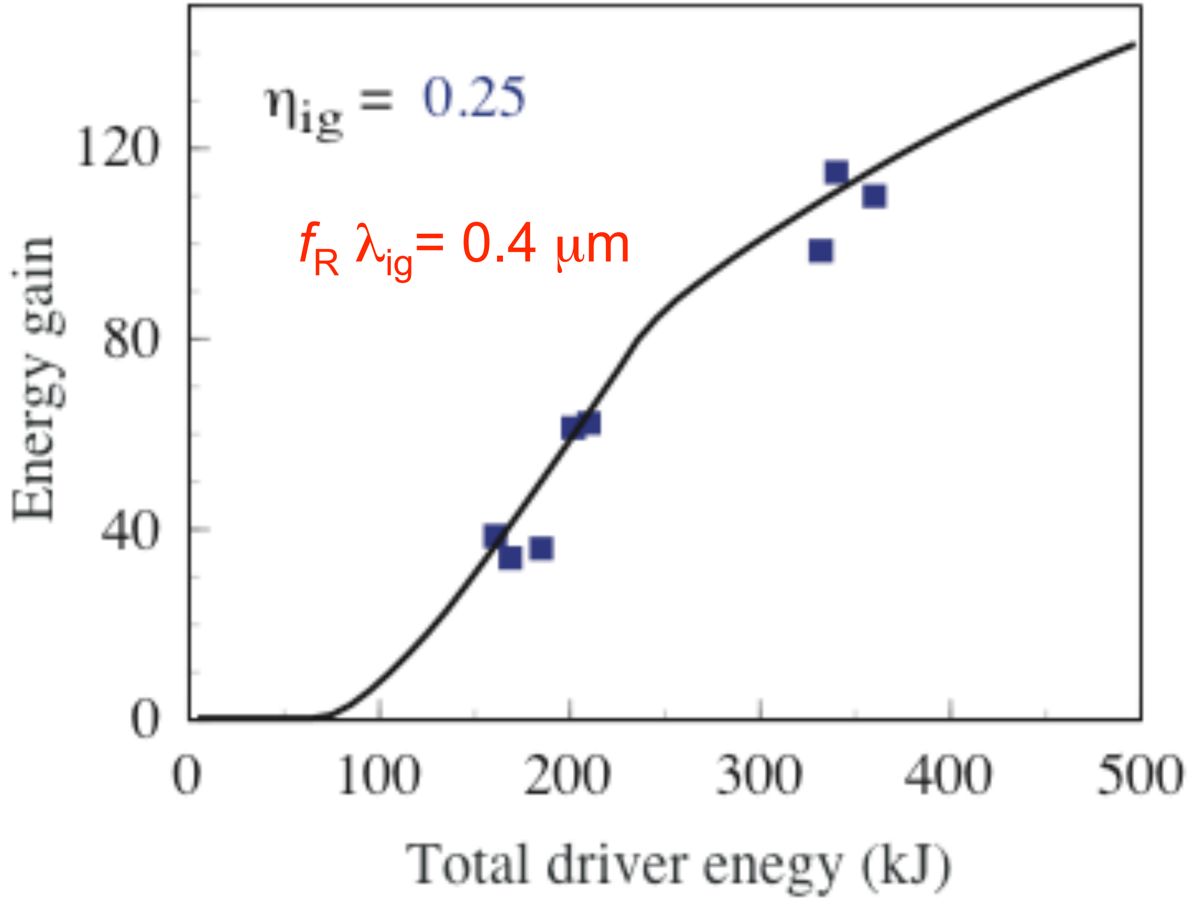
without adiabat shaping



shock ignition

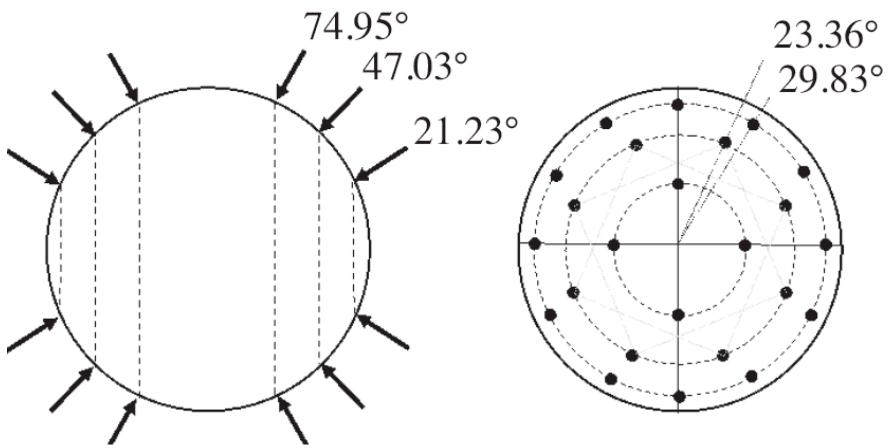


Gain model and scaled targets



assuming good energy coupling (25%), using UV light and limiting ignition energy to 100kJ

Irradiation geometry

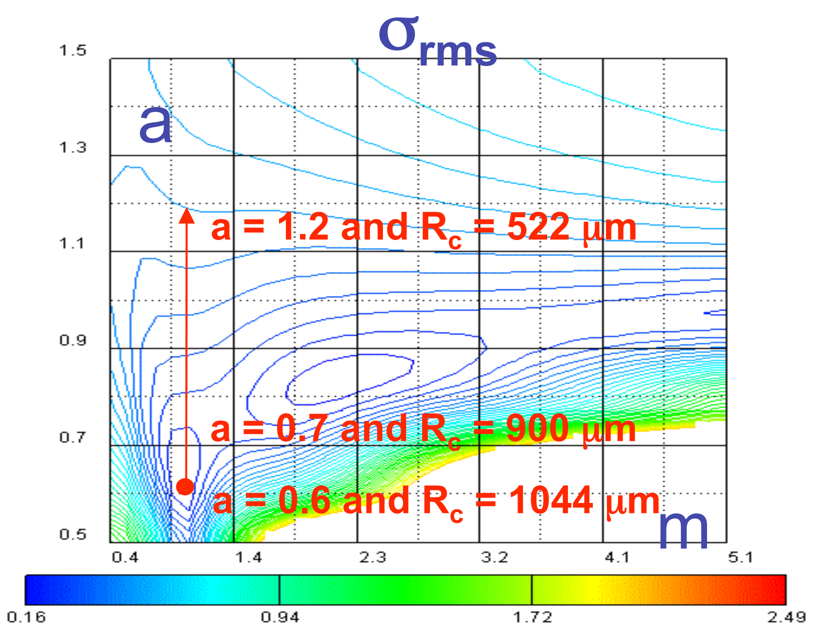


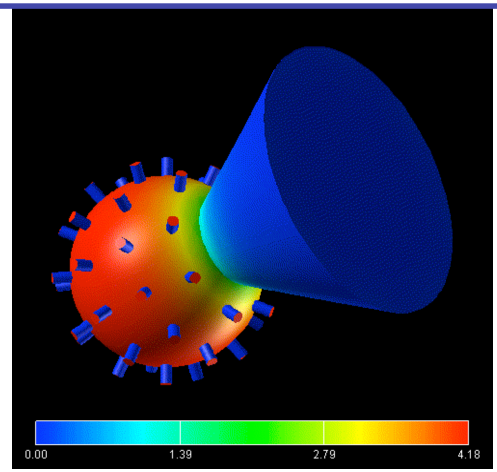
	l-mode
Perfect beam	*12, 8, 10*
Balance (10%)	1, 2, 12, 3
Pointing (5 mrad)	2, 3, 1, 4
centring (2%)	12, 2, 3, 1

Energy balance 94%,

Illumination asymmetry σ_{rms} = 0.15 %

Main low l-modes : 12, 8 and 10 (< 0.004)



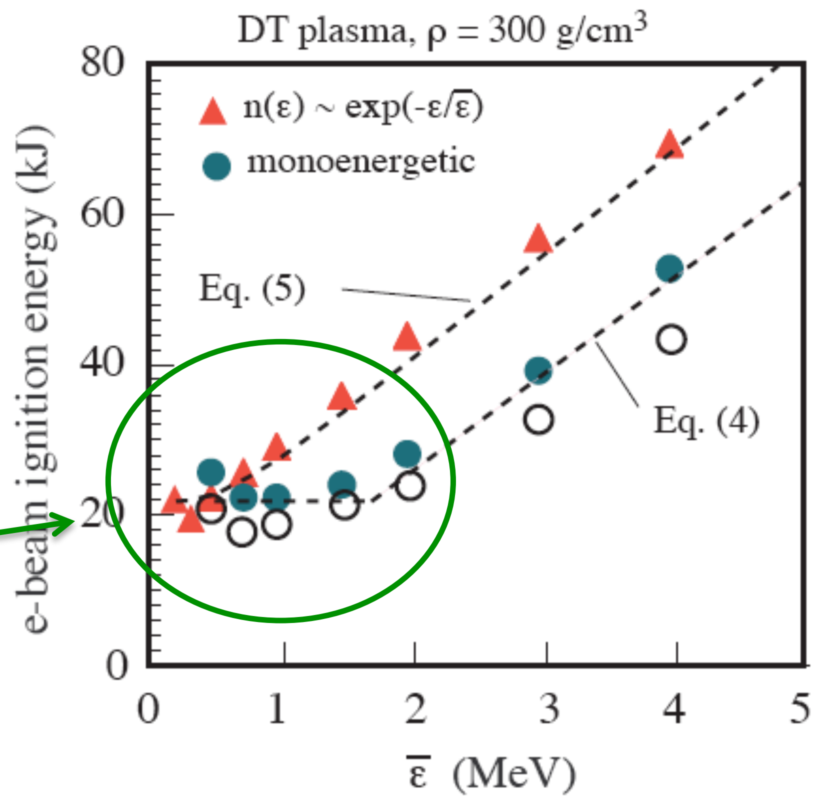


On the cone : 26 % of max intensity
Inside the cone : 2% of max intensity

J.-L. Feugeas and CELIA

Electron beam ignition energy

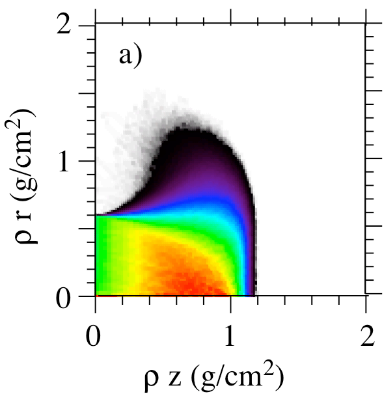
uniform sphere calculations

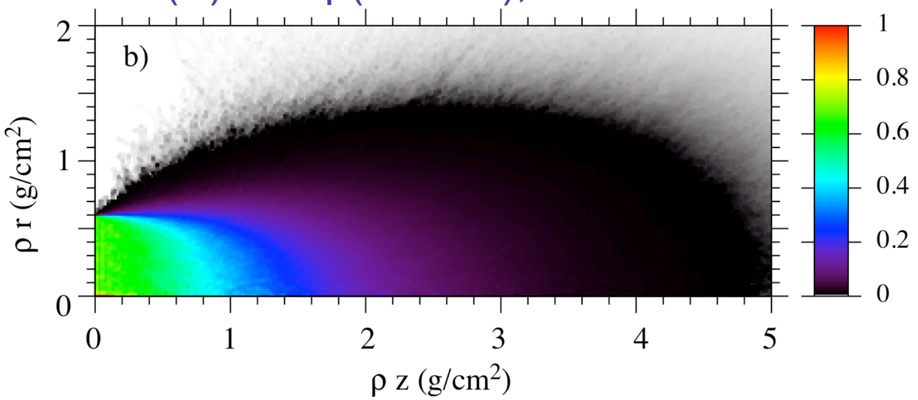


point-like ignition

1.5 MeV electrons

n(E) ∝ exp(-E/<E>); <E> = 1.5 MeV

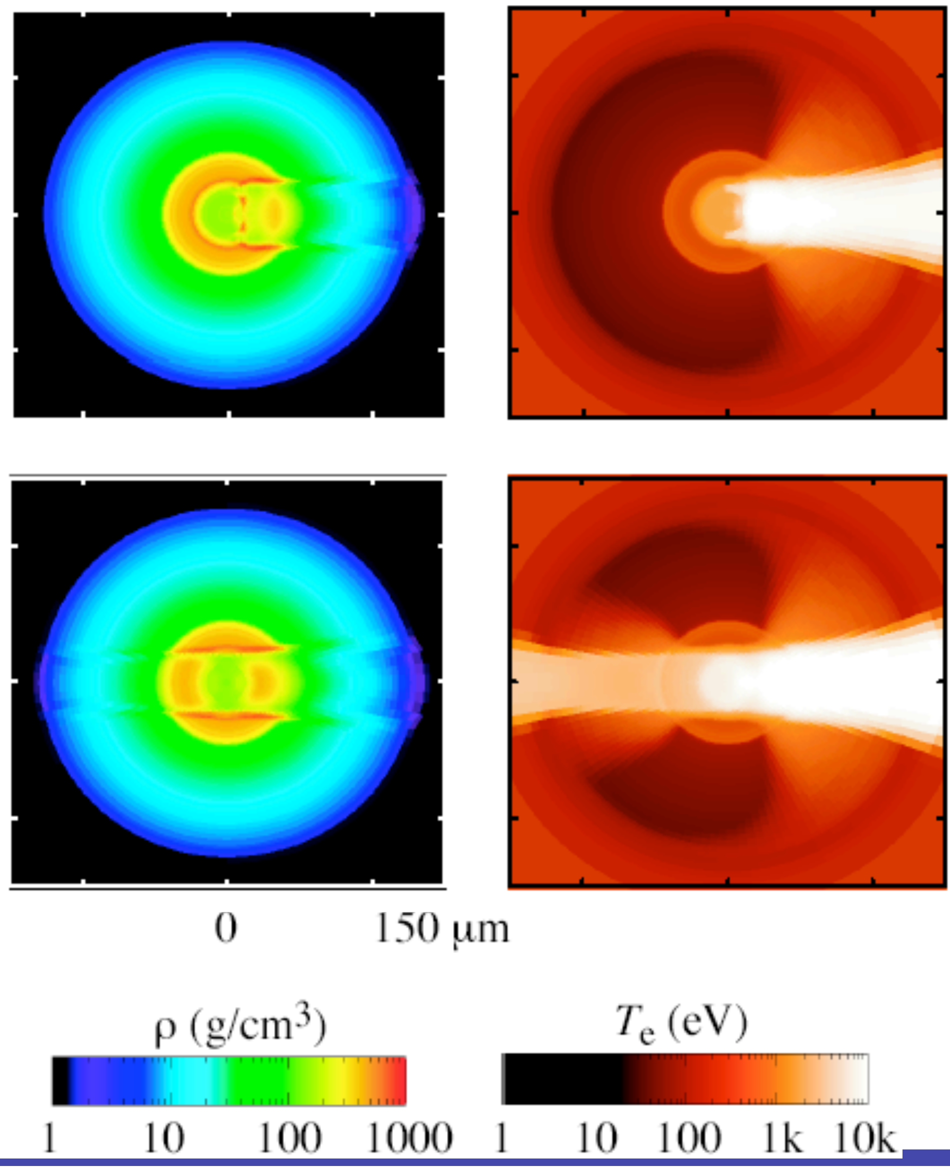




Monochromatic vs Maxwellian

no scattering

Maps at the end of the optimal beam pulse for ignition



monocromatic, $E_e = 1.5$ MeV
cylindrical beam, source at $z = +\infty$
box profiles, $r_b = 20$ μm, $t_p = 16$ ps
no scattering,

beam energy $E_{ig} = 18$ kJ

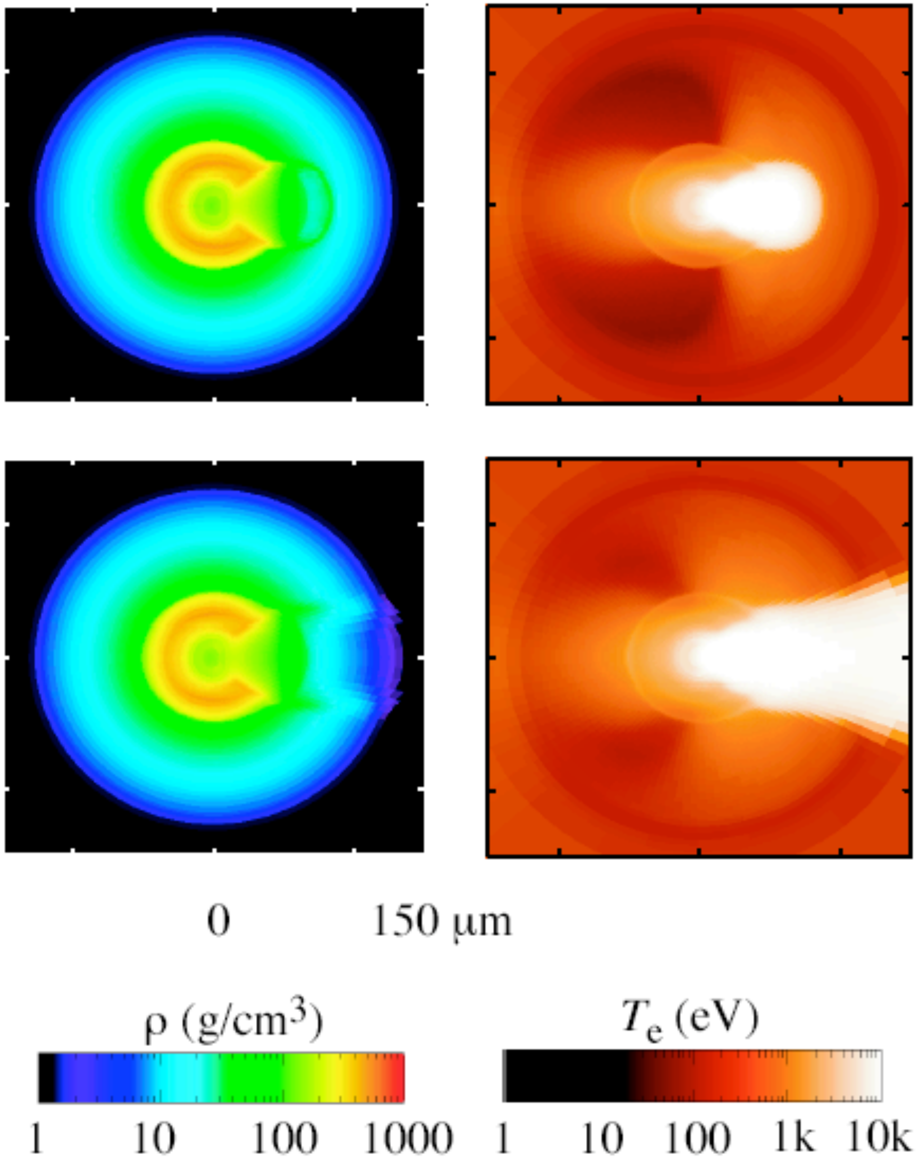
1-D Maxwellian, $\langle E_e \rangle = 1.5$ MeV
cylindrical beam, source at $z = +\infty$
box profiles, $r_b = 20$ μm, $t_p = 16$ ps
no scattering

beam energy $E_{ig} = 32$ kJ

(analogous to Solodov et al., PoP 2007)

Adding electron scattering

Maps at the end of the optimal beam pulse for ignition



1-D Maxwellian, <E_e> = 1.5 MeV
cylindrical beam, **source at z = 70 μm**
Gaussian pulse, r_{HM} = 14 μm, t_{FWHM} = 15 ps
with scattering

beam energy E_{ig} = 38 kJ

1-D Maxwellian, <E_e> = 1.5 MeV
cylindrical beam, **source at z = 150 μm**
Gaussian pulse, r_{HM} = 13 μm, t_{FWHM} = 16.7 ps
with scattering

beam energy E_{ig} = 47 kJ

HiPER

Fast Ignition laser reqrs

For marginal ignition

deposit in the compressed fuel

20x20x20 rule

18 kJ
in 15 ps
in a cylinder of diameter of 30 μm and depth ≤ 1.2 g/cm^2

==> laser

energy: 100 kJ (?)
power: 6 - 7 PW

wavelength: so far, 530 nm (2 ω), *but*

recent experimental results [1] and theoretical work [2] indicate that 1 ω may be OK

[1] Hui Chen et al, PoP, 16, 020705 (2009)
[2] M. Haines et al., PRL, 102, 045008 (2009)

Some crucial issues for F.I.

- Energy conversion efficiency into igniting beam
- Temperature scaling of fast electrons
- Transport of fast electron beam in hot dense plasma
- Range and penetration of electrons in plasmas (collective effects; self-generated e.m. fields)
- Accurate diagnostic tools for compression and ignition
- Cone effects on compression and fuel contamination

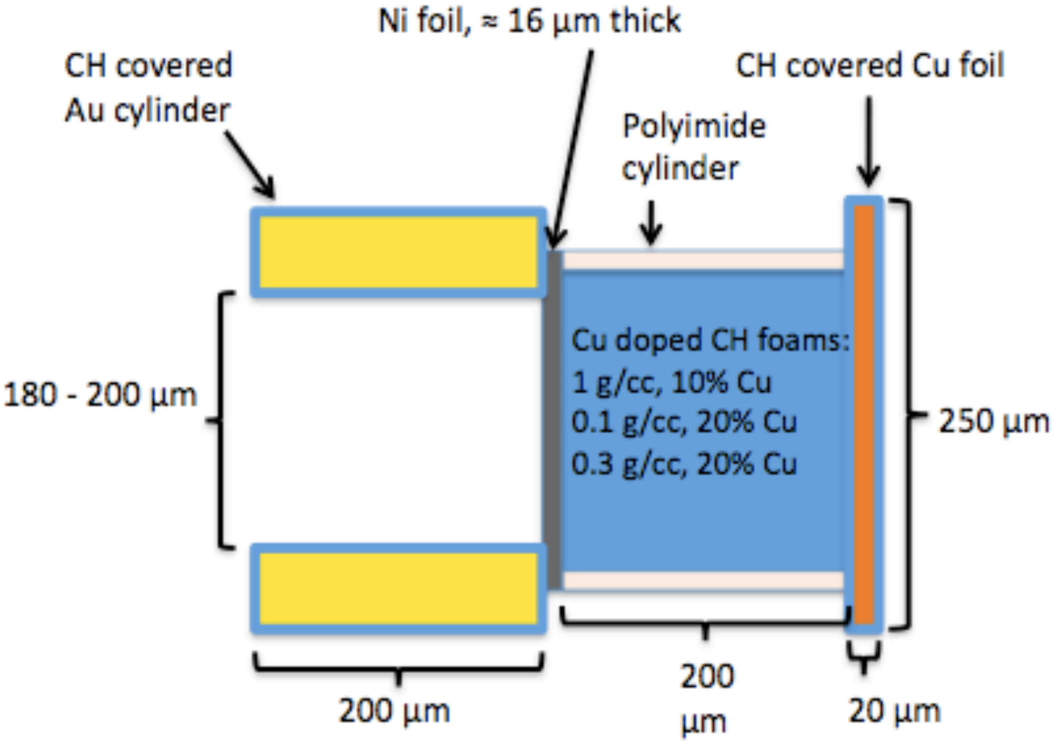
HiPER

Fast-electron transport in cylindrically compressed matter

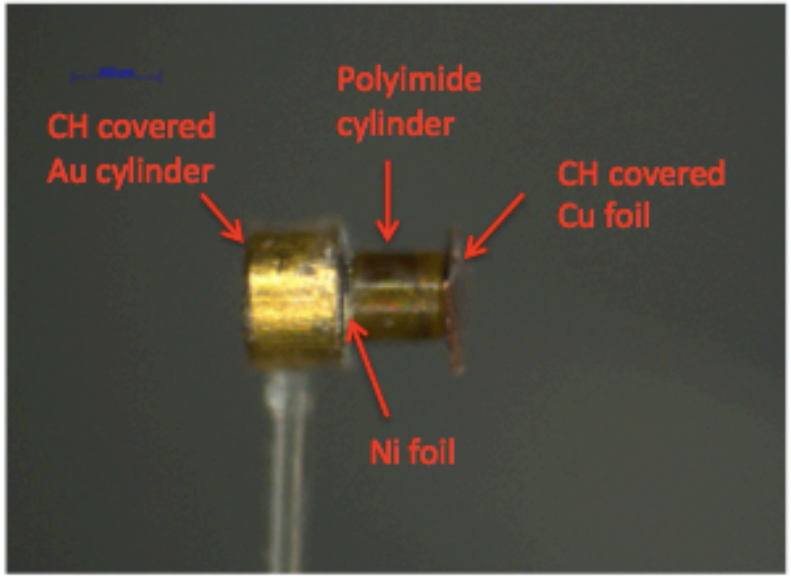
RAL-TAW Experiment : October - December 2008

LULI	M. Koenig, S. Baton, F. Perez
Milano-Bicocca	D. Batani, R. Jafer, L.Volpe
CELIA	F. Dorchies, J. Santos, C. Fourment, S. Hulin, P. Nicolai, B. Vauzour
RAL	K. Lancaster, M. Galimberti, R. Heathcote, Ch.Spindloe, H.Lowe
Pisa	P. Koester, L. Labate, L. Gizzi
Bologna	C. Benedetti, A. Sgattoni
Roma	M. Richetta
York	J. Pasley
UCSD	F. Beg, S. Chawla, D. Higginson
LLNL	A. MacKinnon, A. McPhee
Univ. Madrid	J. Honrubia

Very large European collaboration !!
Good interaction theory / experiment !!
Good collaboration with the US !!



Cross section

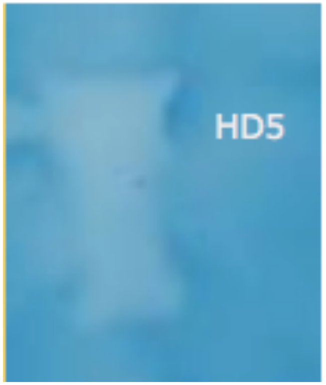


Actual Target

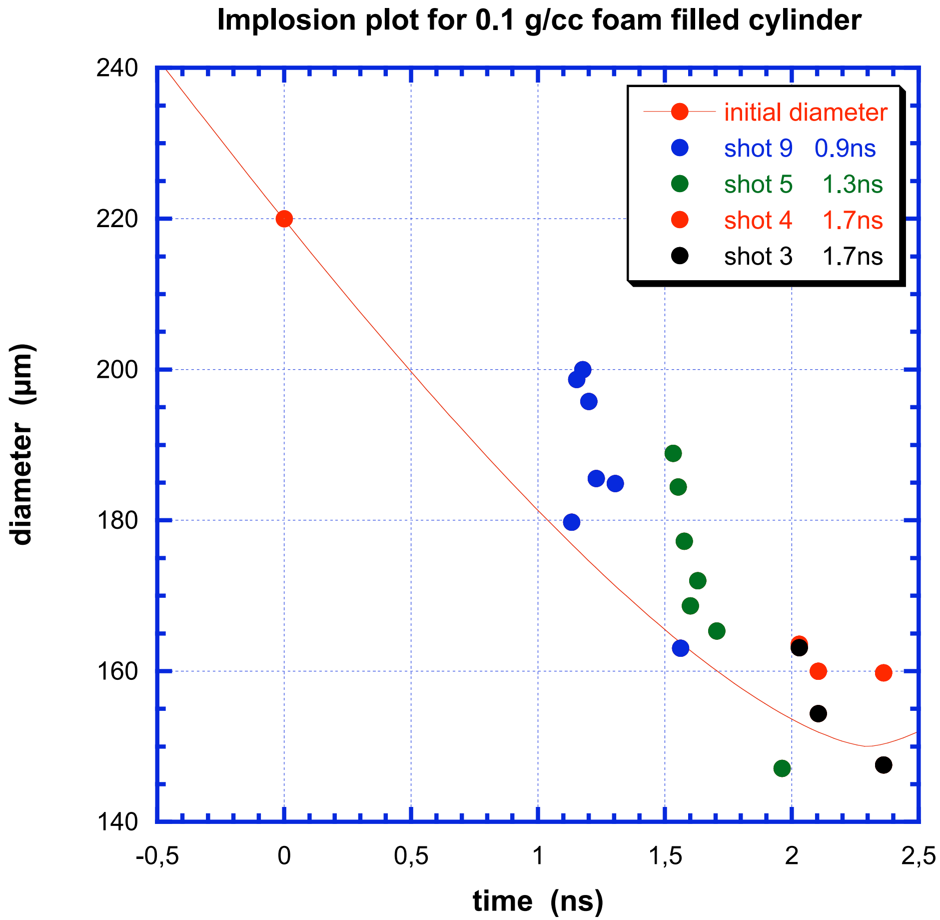
Proton and X-ray radiography used to follow target implosion

0 ns, ref target, 220 μm

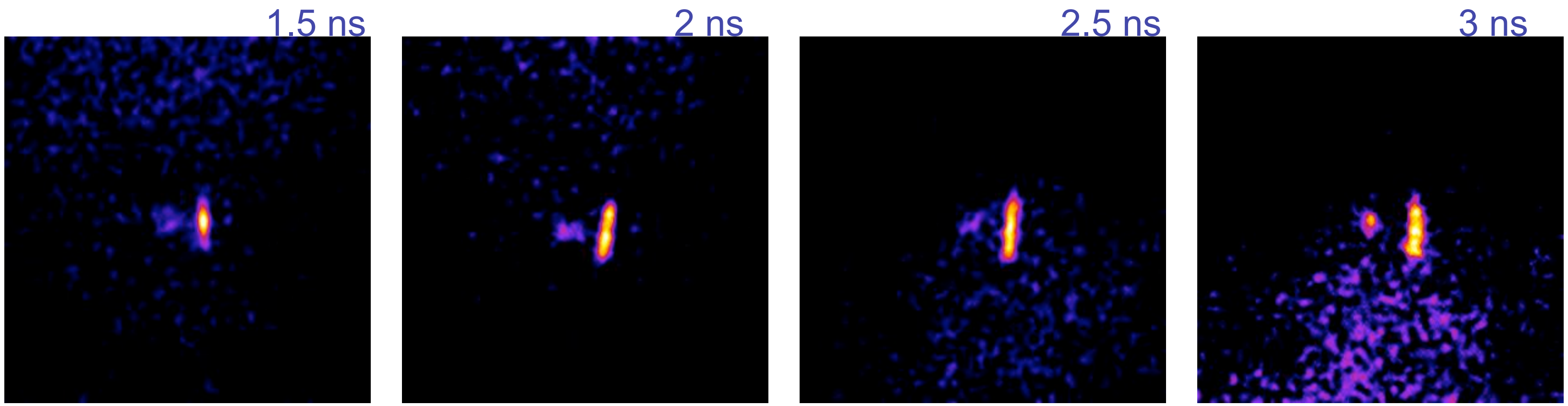
1.56 ns,
shot 5,
177 μm

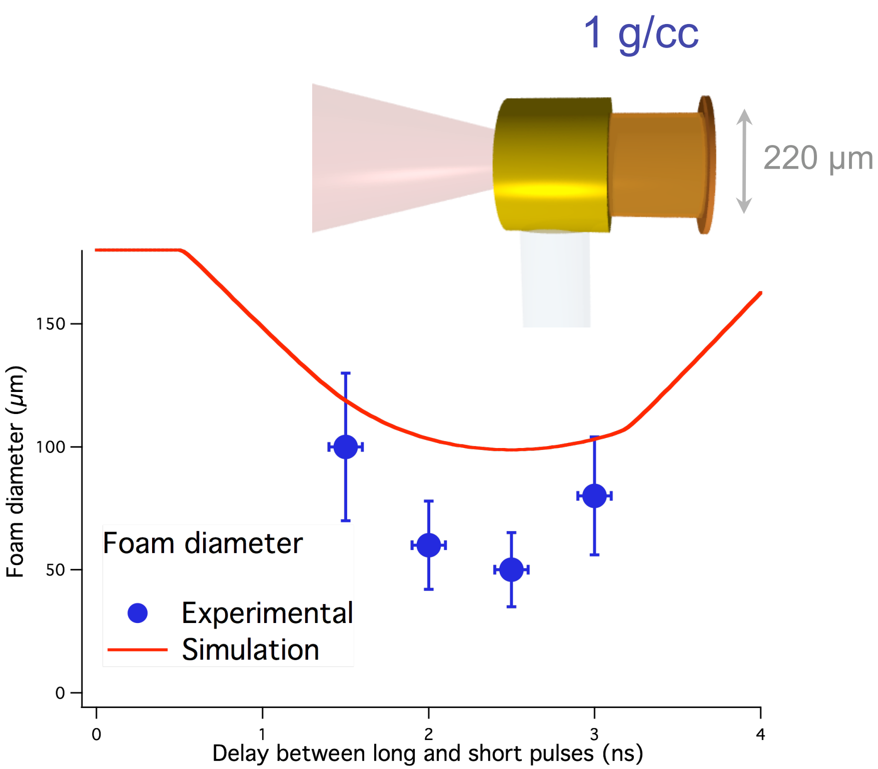


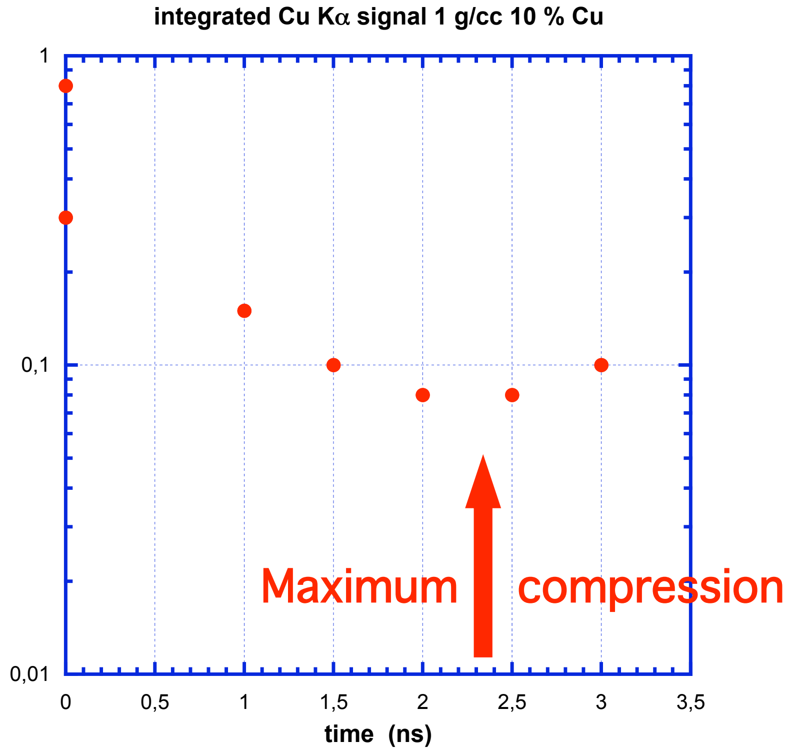
2.5 ns, shot 3,
147 μm



Results from 2D crystal imager (Cu K-α)







Proposed collaborations

OMEGA laser facility offers the opportunity to perform experimental investigations that are HiPER-relevant and that are fundamental for addressing the most important uncertainties of present theoretical and numerical modelling.

OMEGA presentations and discussions in WGs will give shape to possible ways of collaboration, both on numerical modelling and experimental activities.