Direct-drive target implosion at the deceleration phase in the presence of hydrodynamic instabilities

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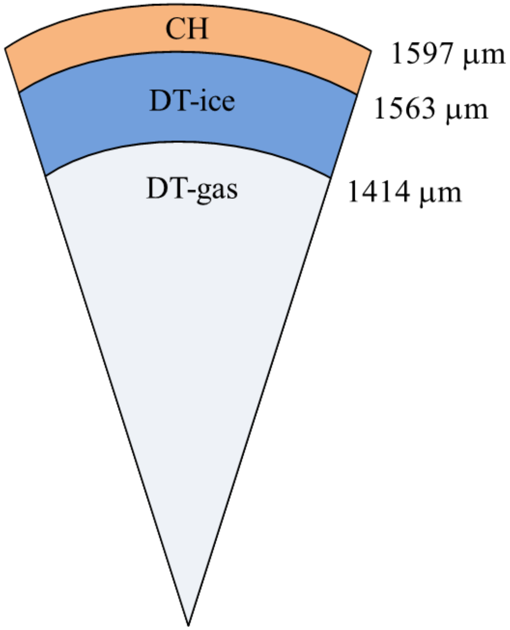
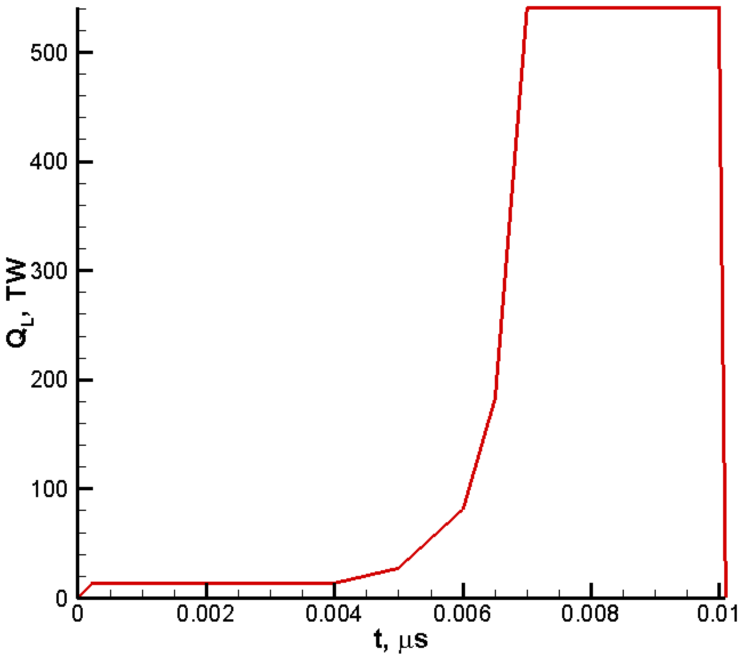
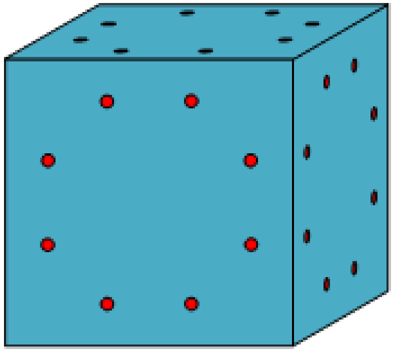
Outline

- Initialisation of multi-dimensional calculations of thermonuclear target implosion
- Results of 3D modeling of the compression in presence of perturbations
- Energetic characteristics of the compression dynamic
- The influence of perturbation growth on the thermonuclear reactions rate
- Final remarks

Target design & system of irradiation





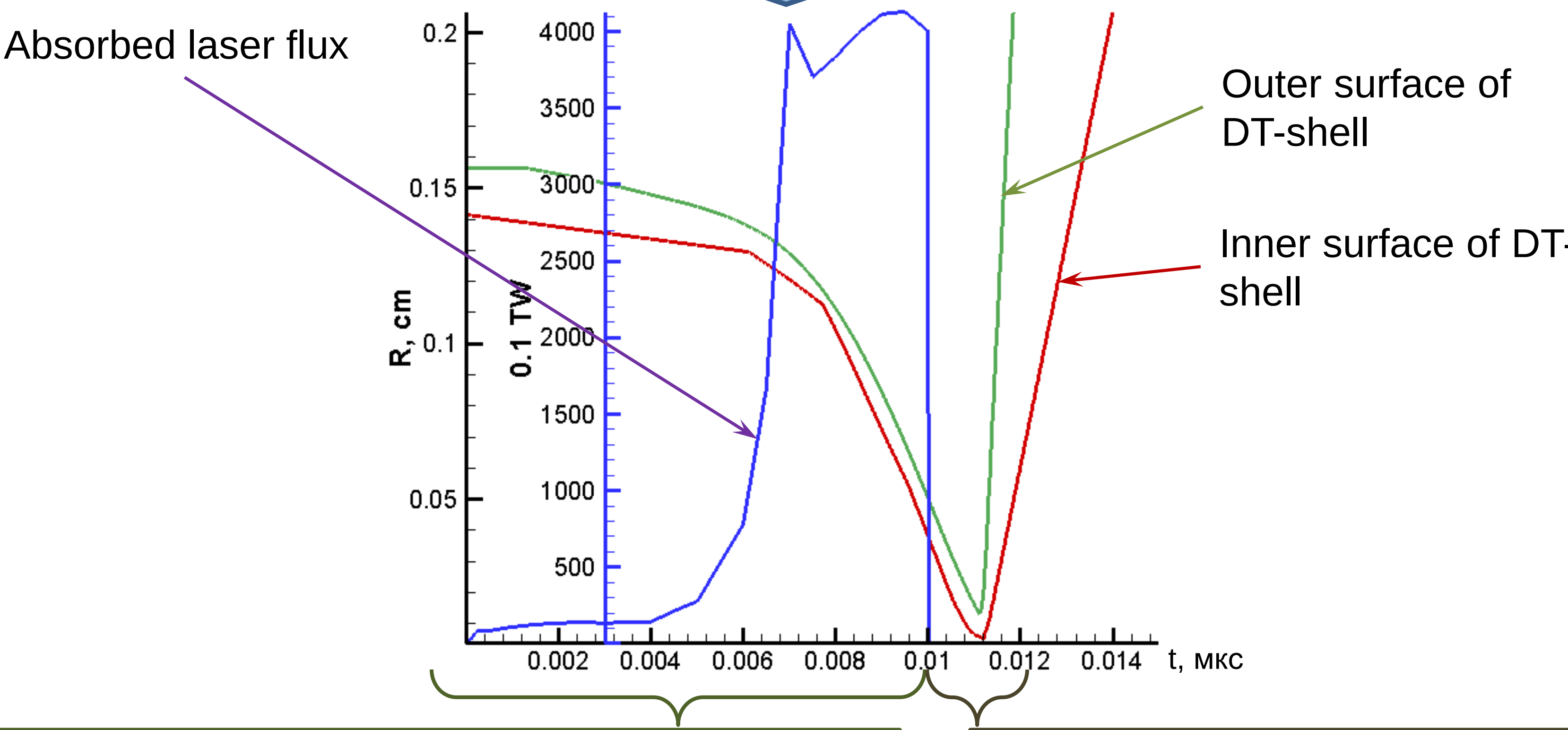


- Baseline target design*
- Incident laser flux
- System of laser beams for target irradiation

*Bel’kov S.A. et al., Thermonuclear targets for direct-drive ignition by a megajoule laser pulse, JETP, 121, 4, 686-698, 2015

2D/3D problems setup

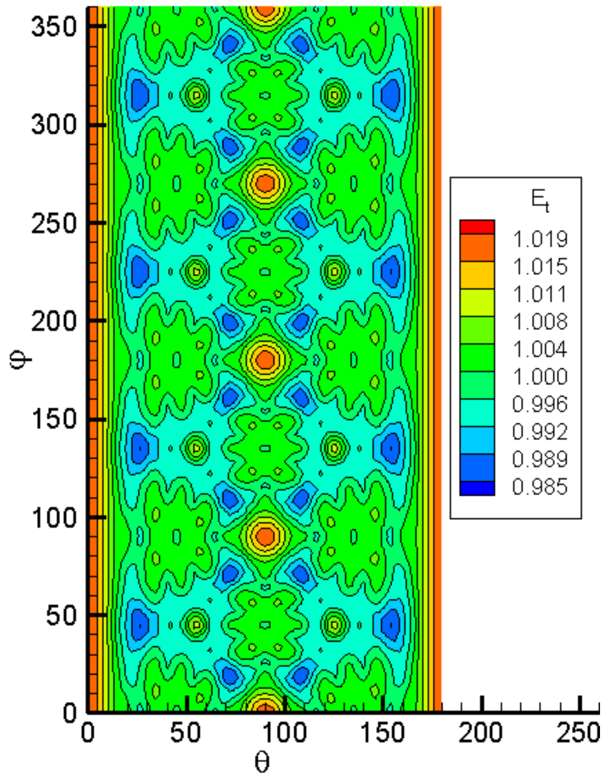
I.1D calculation of the laser energy absorption in the target using numerical code RAPID

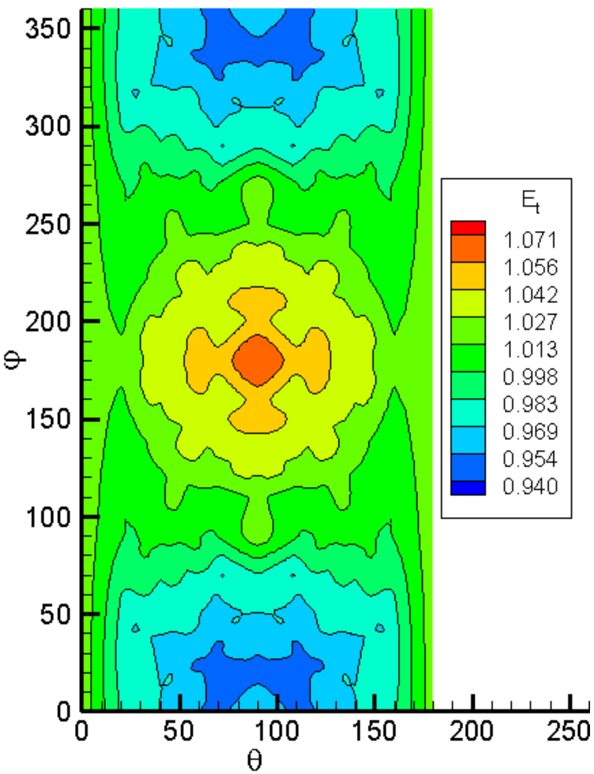


II. 1D spherically symmetric calculation using DIANA program

III. Multidimensional modeling of the deceleration phase

Non-uniformity of laser energy absorption*





Angle distributions of total absorbed laser energy:
a) under conditions of standard target irradiation by laser system,
b) in the case of target offset along 0x axis on 80 μm.

*Refer Thursday poster session for details - Demchenko N.N. et al., No.2

Initial perturbations for 3D modeling*

Based on the laser energy absorption map one can define dominant mode of the perturbation as $l = 6-8$

$$U_r^{3D} = U_r^{1D}\left(1+\delta U_r\right), \quad \delta U_r = \sum_{l,m} a_{lm} Y_{lm}\left(\theta,\varphi\right)$$

$$a_{lm} = a_{\max}/l^2, \quad a_{\max} = 0.04 \text{ (a)}, \quad a_{\max} = 0.12 \text{ (b)}$$

Two types of perturbations are considered for modeling

Symmetric with respect to the origin (I)

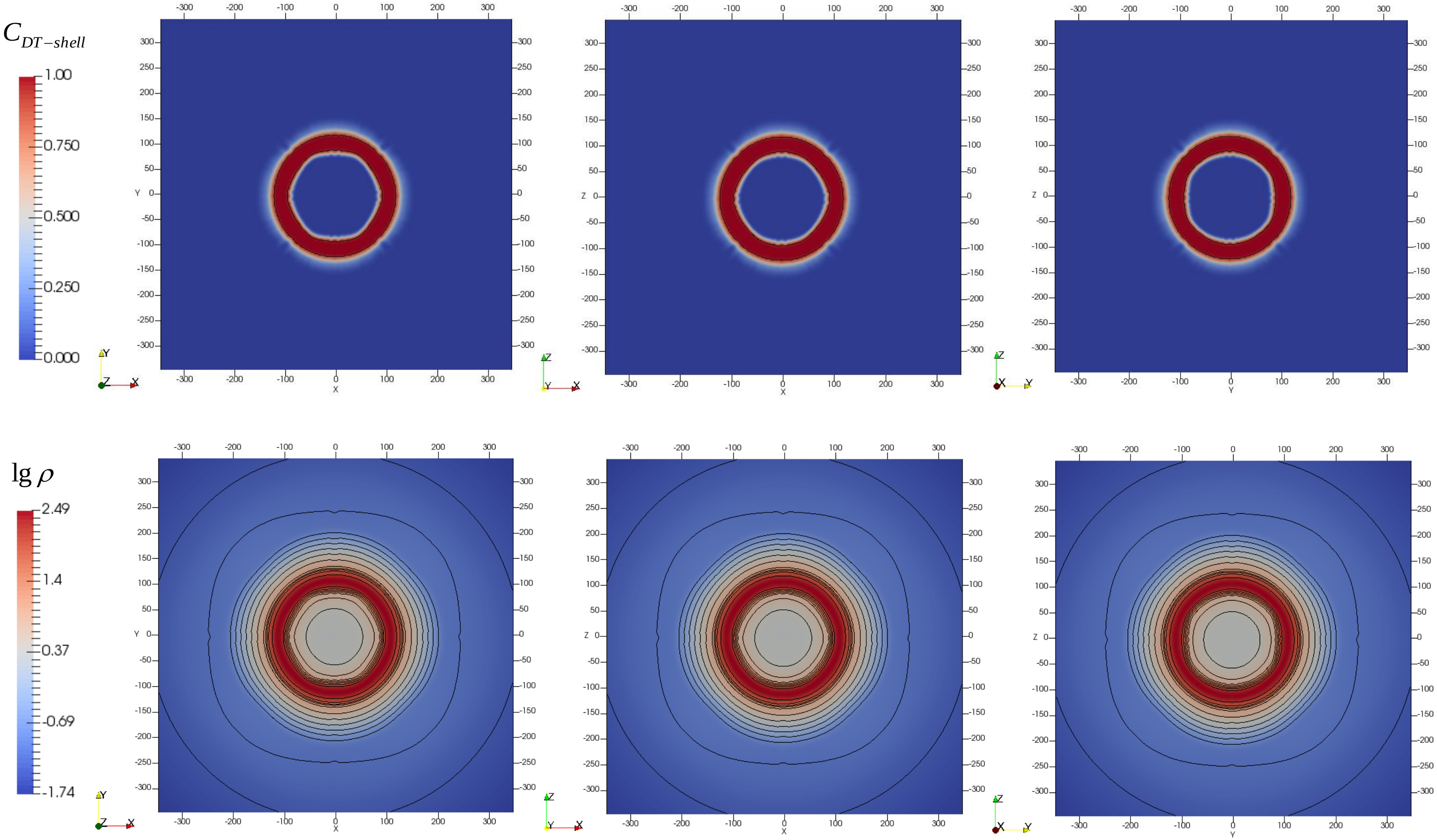
$$l = 8, \quad m = 6$$

Non-symmetric with respect to the origin (II)

$$l = 1, 2, 4, 6, 8, \quad m = \overline{1, l}$$

*Refer Wednesday oral session for detailed 2D calculations of target compression and burning based on distributions of absorbed laser energy - Yakhin R.A. et al., We19_0

Target at peak compression – I-a

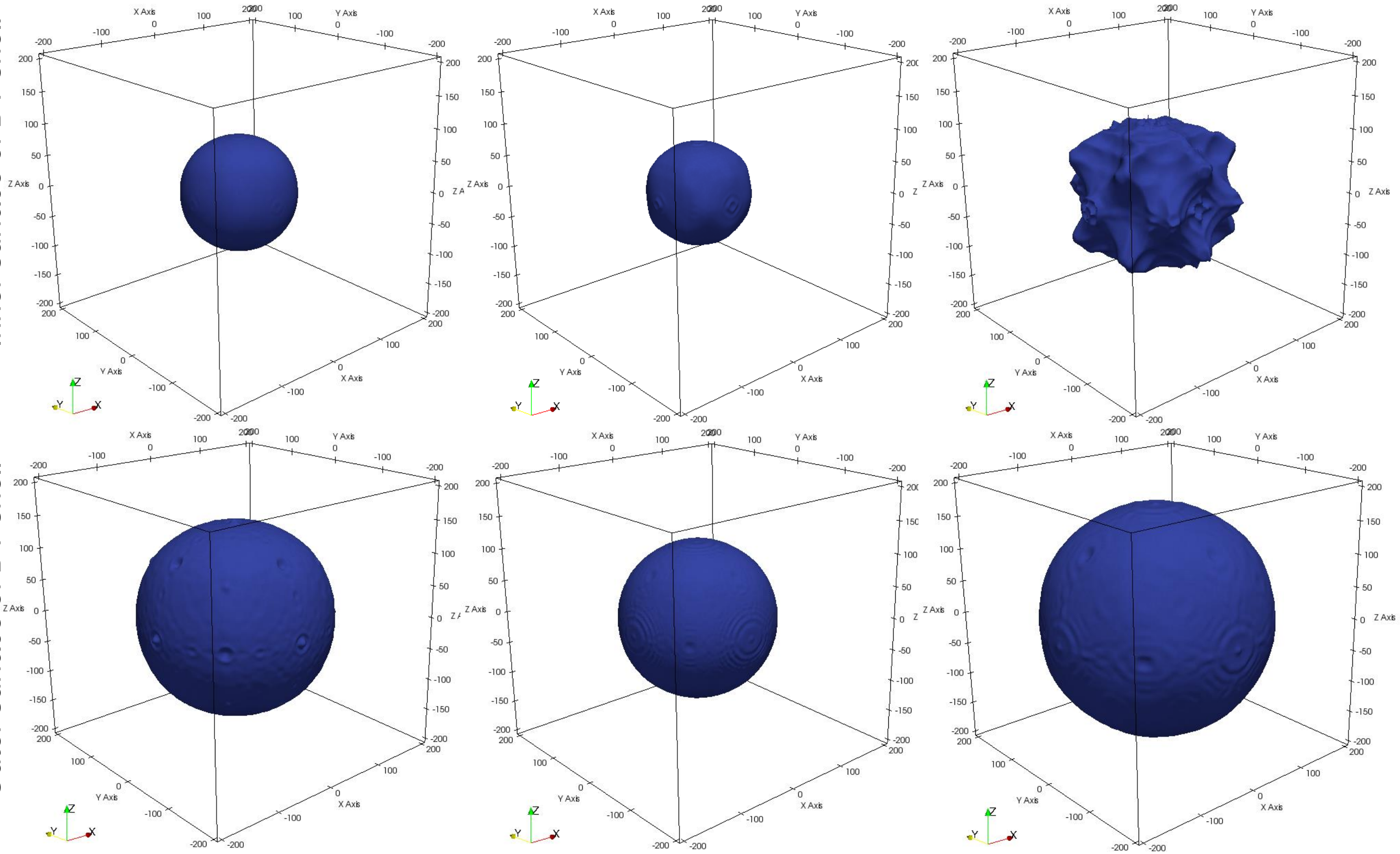


t = 1.2 ns (+10 ns)

Dynamic of the compression – I-a

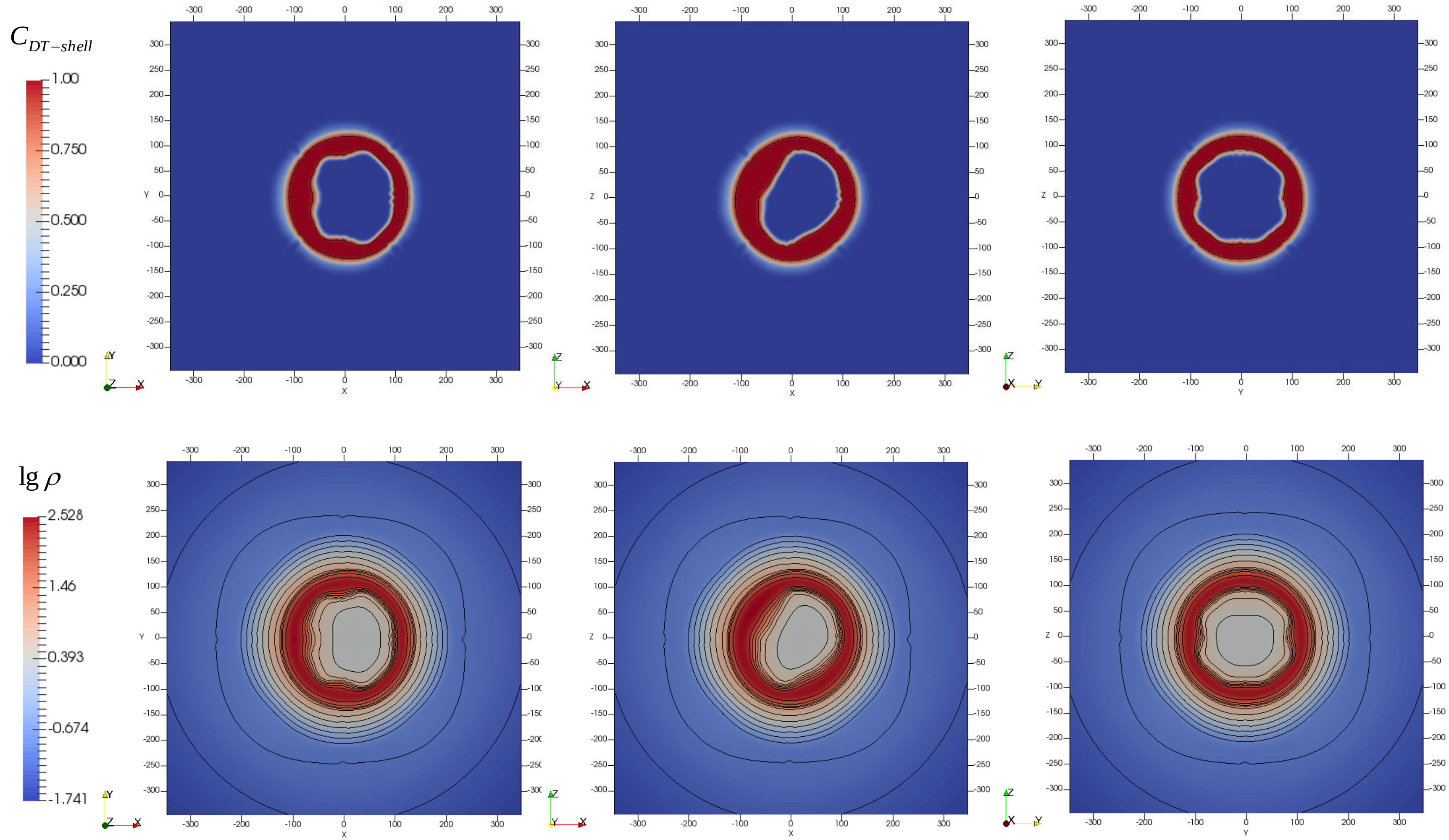
Inner surface of DT-shell

Outer surface of DT-shell



t = 1.0 ns (+10 ns) | *t* = 1.2 ns (+10 ns) | *t* = 1.5 ns (+10 ns)

Target at peak compression – II-a

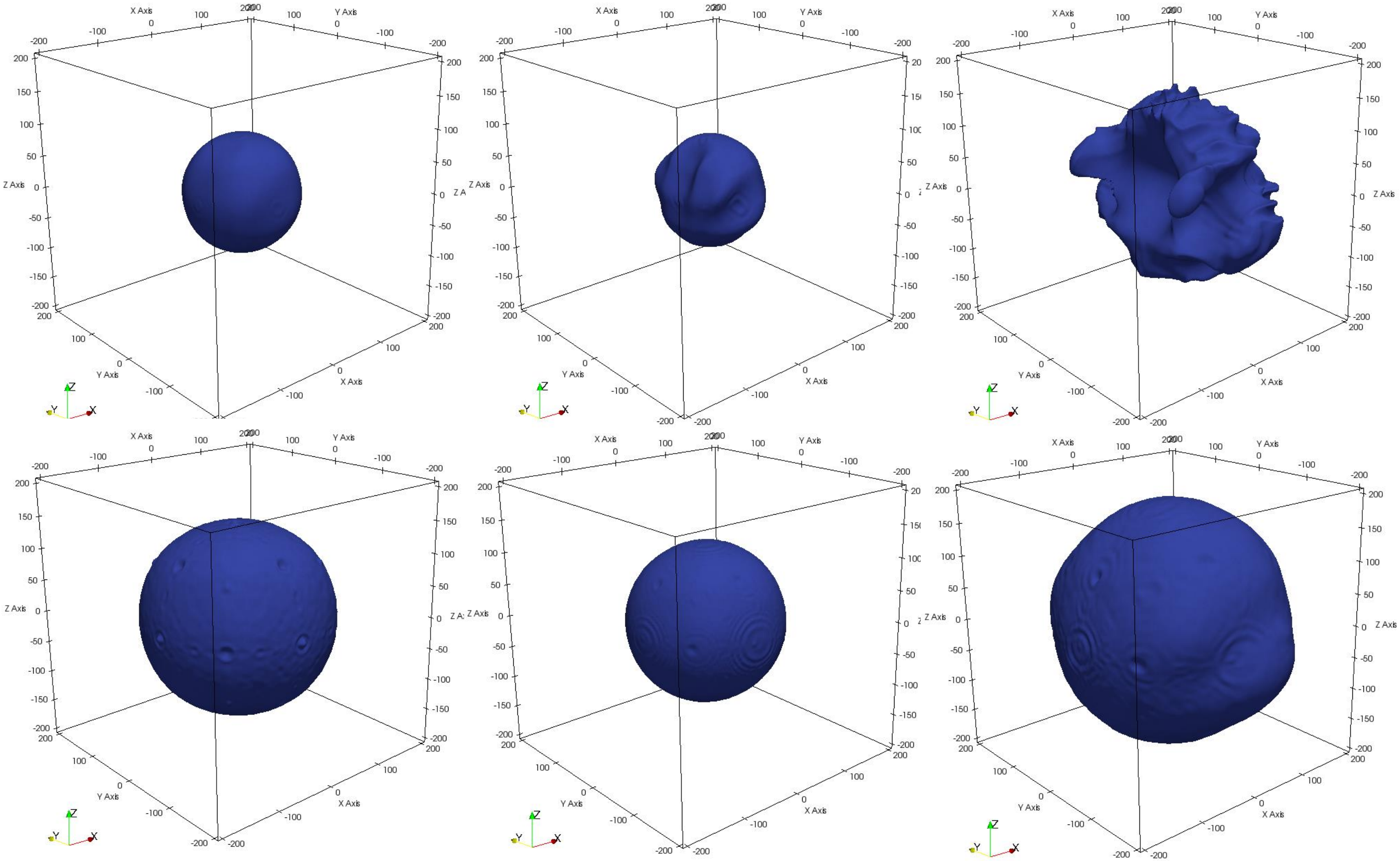


t = 1.2 ns (+10 ns)

Dynamic of the compression – II-a

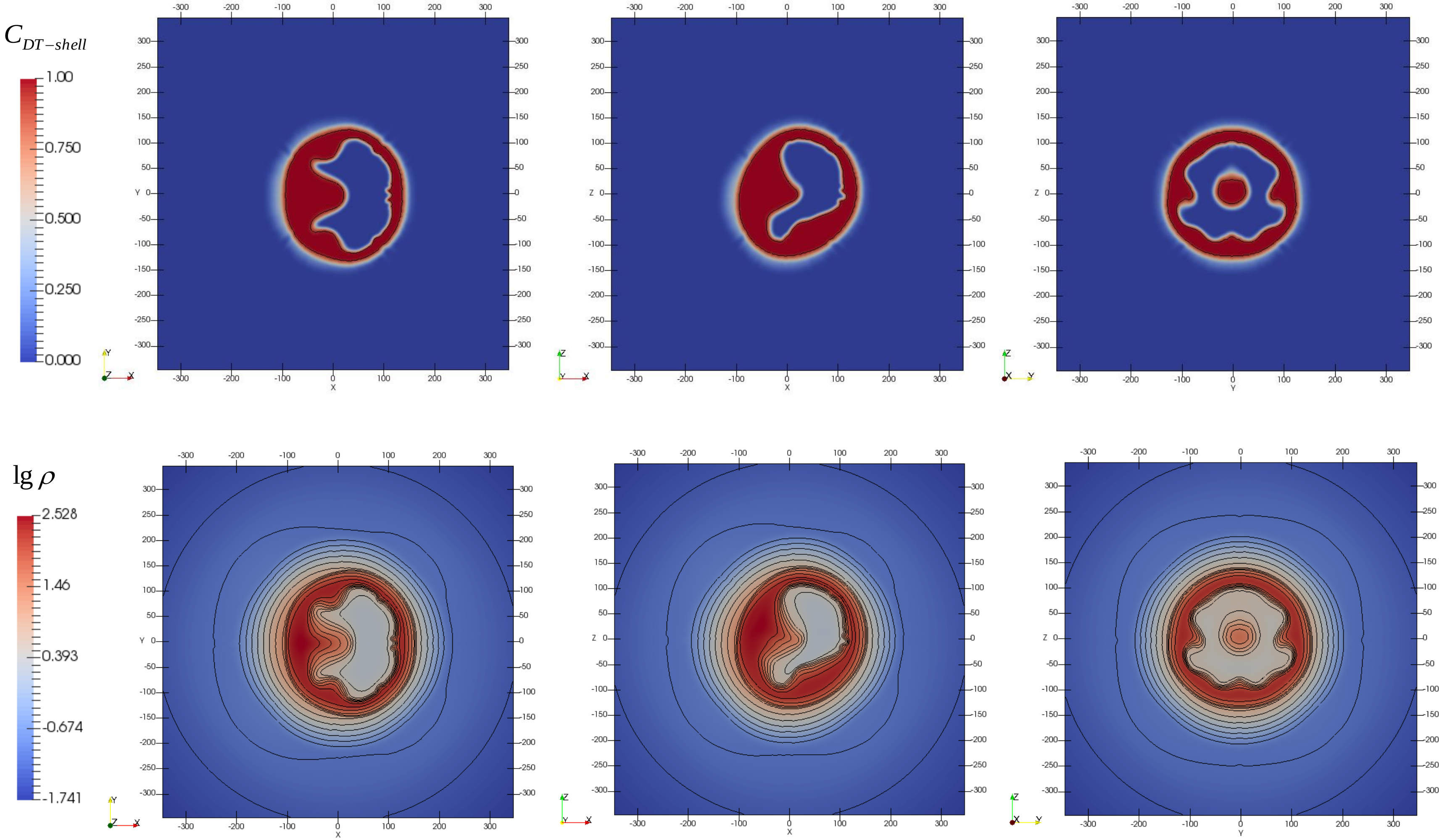
Inner surface of DT-shell

Outer surface of DT-shell



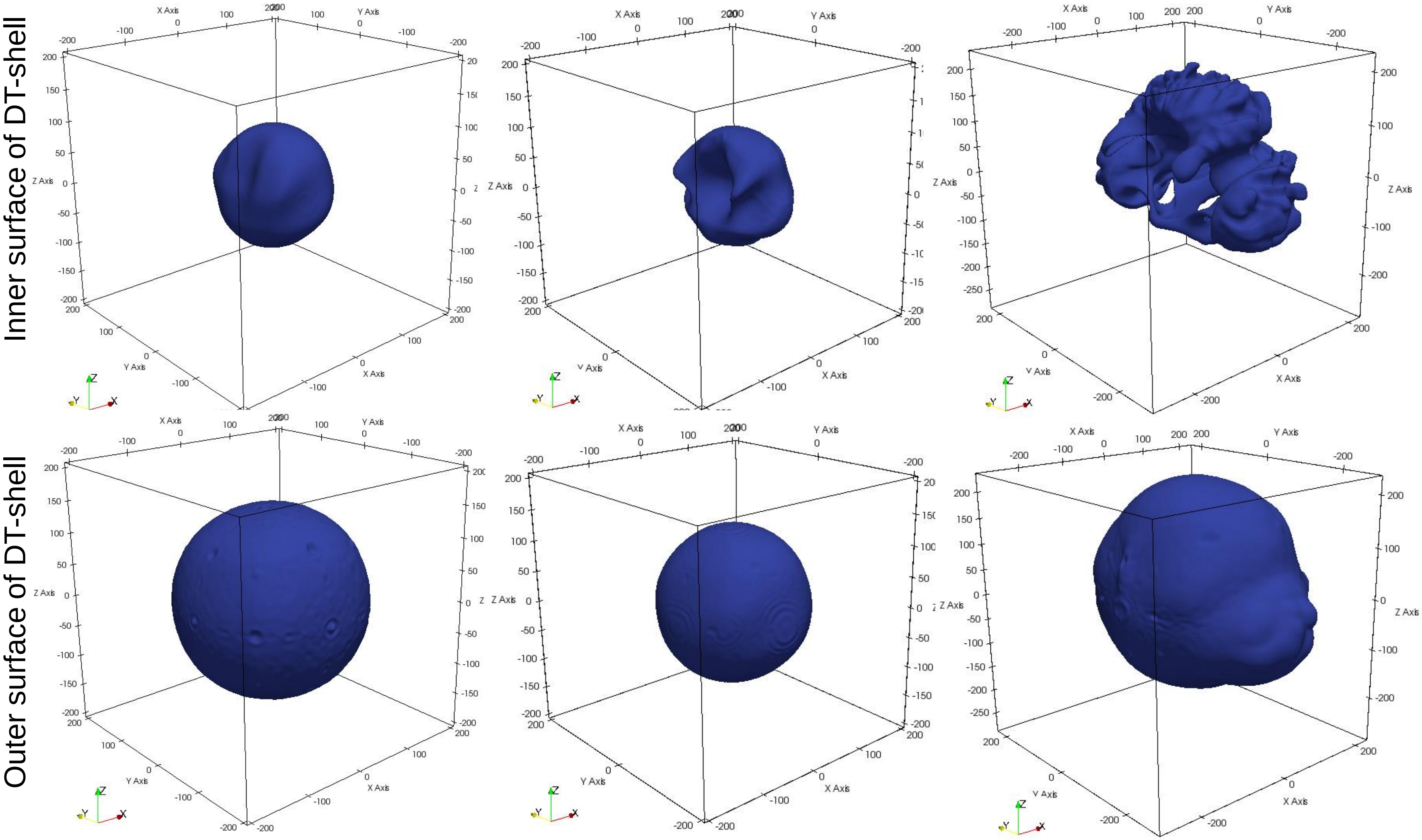
t = 1.0 ns (+10 ns) t = 1.2 ns (+10 ns) t = 1.5 ns (+10 ns)

Target at peak compression – II-b



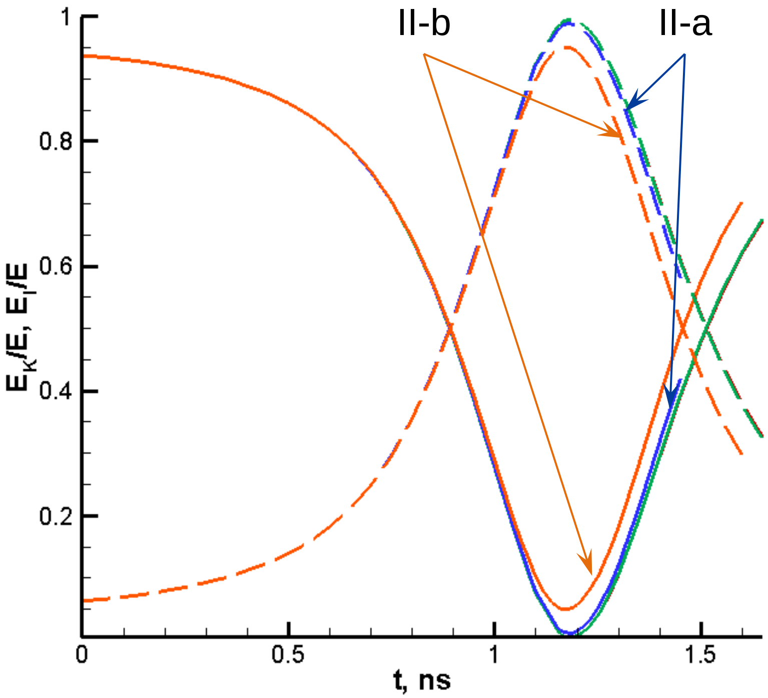
t = 1.2 ns (+10 ns)

Dynamic of the compression – II-b

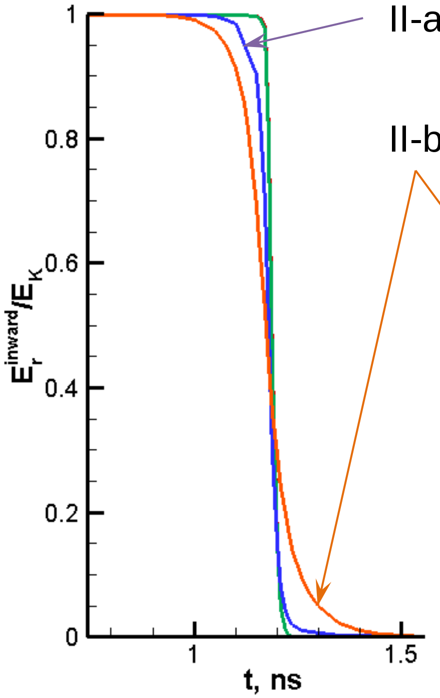


t = 1.0 ns (+10 ns) t = 1.2 ns (+10 ns) t = 1.5 ns (+10 ns)

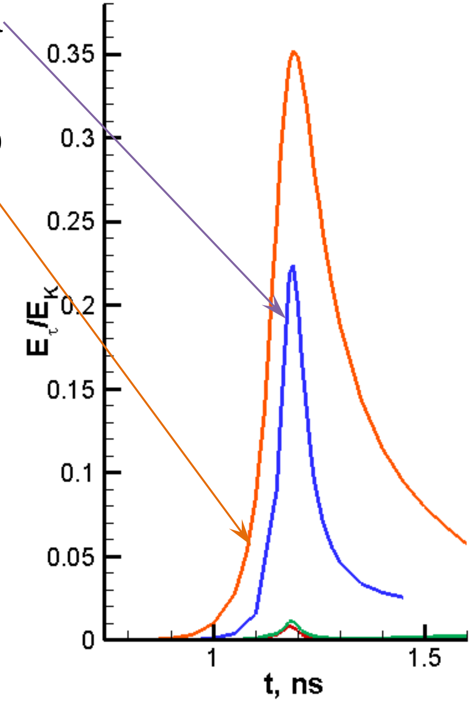
Energetic characteristics of the compression



The ratio of DT-fuel kinetic and internal energies and total DT energy for various 3D calculations



The part of DT-fuel kinetic energy per inward motion for various 3D calculations

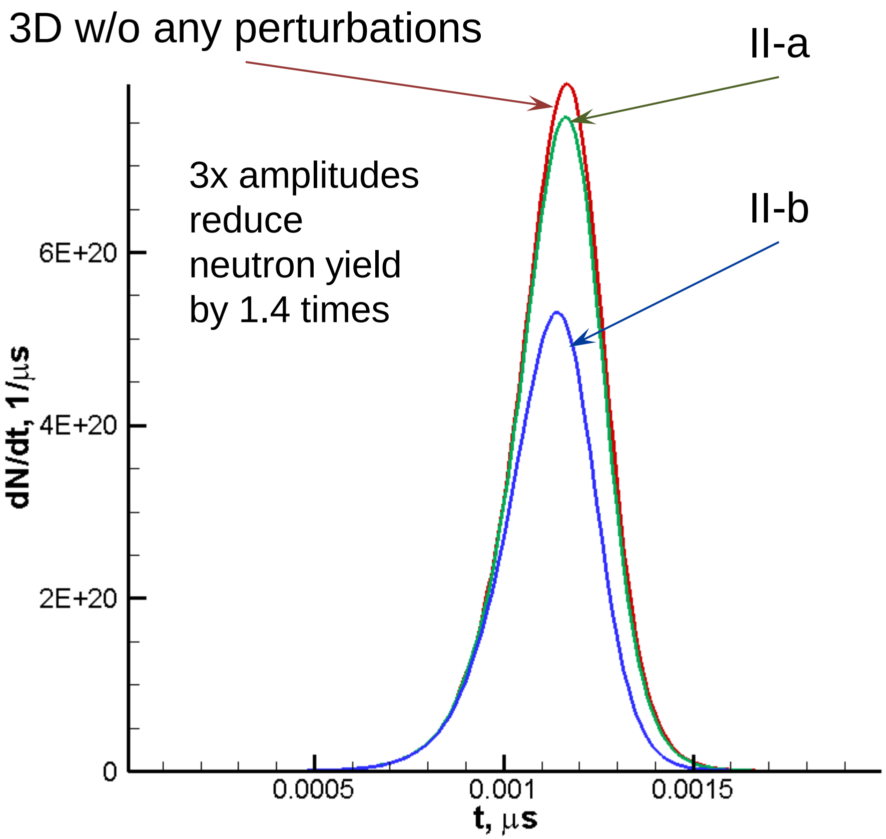


The part of DT-fuel kinetic energy per non-radial for various 3D calculations

Target compression and burning

Preliminary calculations using numerical code MARPLE3D*

Two-temperature hydrodynamics
+
Thermal conduction
+
Electron-ion relaxation
+
Volume radiation loses
+
Thermonuclear burning and local energy deposition from *α*-particles



*Gasilov V.A. et al., Program package MARPLE3D for simulation of pulsed magnetically driven plasma using high performance computing, Matem. Mod., 24, 1, 55-87, 2012

Final remarks & conclusions

- The presence of perturbations leads to poorer and longer conversion of DT-shell kinetic energy into internal energy of the hot spot that worsens conditions in the center of the target and as a consequence reduces the rate of the thermonuclear reactions

- The part of unconverted kinetic energy is contained in motion, mainly in radial direction and less in others, of spikes and bubbles induced by initial radial velocity perturbations

- Greater amplitude of the perturbations leads to bigger values of kinetic energy in non-radial directions at peak compression

Thank you for your attention!