INDIRECT DRIVE TARGET EXPERIMENTS ON ISKRA-5 FACILITY WITH LASER BEAMS ON SECOND HARMONIC

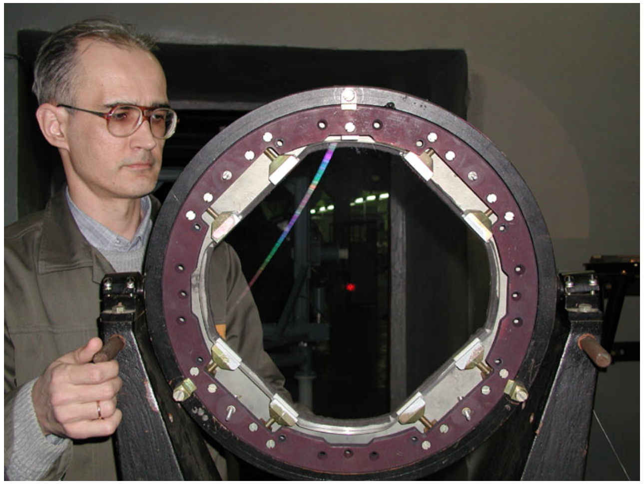
V.I.Annenkov, S.A.Belkov, A.B.Bessarab, S.V.Bondarenko, O.A.Vinokurov, S.G.Garanin, R.V.Garanin, G.V.Dolgoleva, N.V.Jidkov, V.P.Kovalenko, G.G.Kochemasov, A.G.Kravchenko, V.A.Krotov, D.N.Litvin, P.Yu.Lopatin, S.P.Martynenko, E.I.Mitrofanov, V.M.Murugov, A.V.Senik, K.V.Starodubtsev, N.A.Suslov, G.V.Tachaev

Outline

- ISKRA-5 laser facility: common parameters and set of diagnostics
- Indirect drive target
- The main results of the first experiments with indirect drive targets on ISKRA-5 facility using second harmonic laser pulse
- 1D and 2D calculations for conditions of laser ISKRA-5 and its comparison with experimental data

ISKRA-5 Laser Facility

Facility building



The DKDP crystal for laser beam conversion to second harmonic

Main parameters

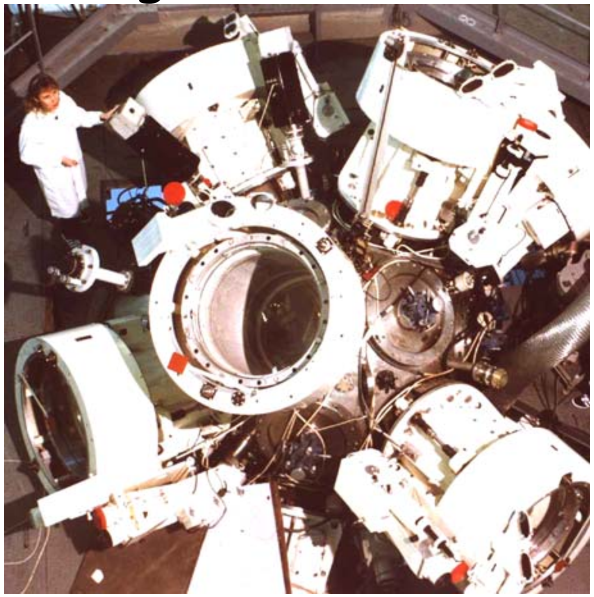
Laser energy	30 kJ
Wavelength	1,315 mcm
Pulse duration	0,3 ns
Beams	12

In 2004 the upgrade of ISKRA-5 facility was finished and full scale experiments with second harmonic started. Now ISKRA-5 has:

wavelength – 0.656 mcm; laser energy – 2÷3 kJ; pulse duration – 0.4-0.5 ns

Target chamber and diagnostics

Target chamber

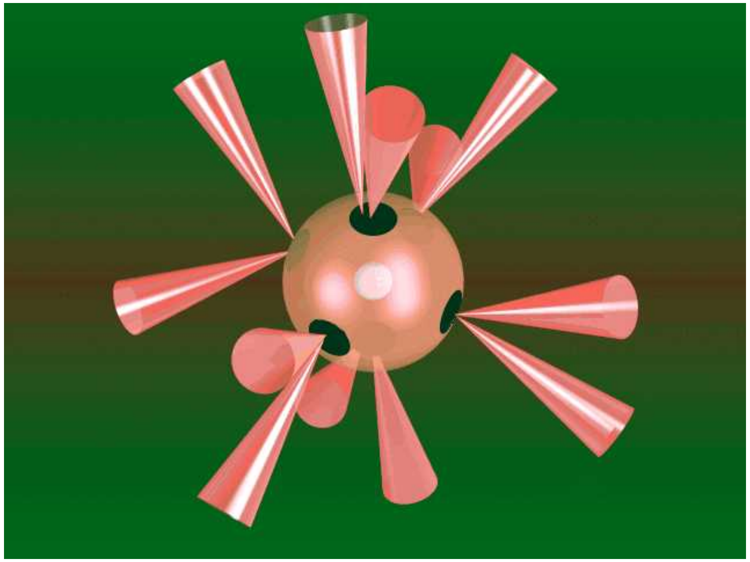


12 lens focusing system with focusing length 1600 mm, beam diameter - 300 mm.

Set of diagnostics

1. Energy balance - array of light and plasma calorimeters.
2. Control of laser pulse parameters.
3. Laser interferometry for control of target plasma expansion.
4. Measurements of ion fluxes:
   - Faraday caps;
   - Thomson mass spectrometer.
5. Pinhole cameras. Multi frame pinhole camera.
6. Measurement of X-ray spectrum:
   - Dante X-ray spectrometer (0.1-1.5 keV);
   - Array of X-ray and P-i-N diodes (1.5-100 keV);
   - X-ray streak cameras.
7. Set of X-ray spectrographs:
   - Transmission grating;
   - Grazing diffraction grating;
   - Flat crystals.
   - Cylindrical and spherical crystals.
8. Neutron yield – Cu and In activation method.
9. Fuel temperature – time of flight measurement.

ISKRA-5 indirect drive experiments

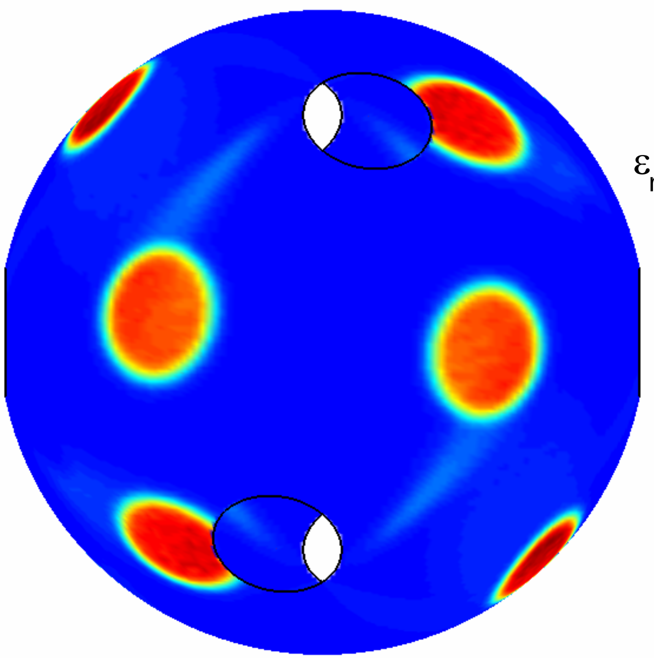


Target

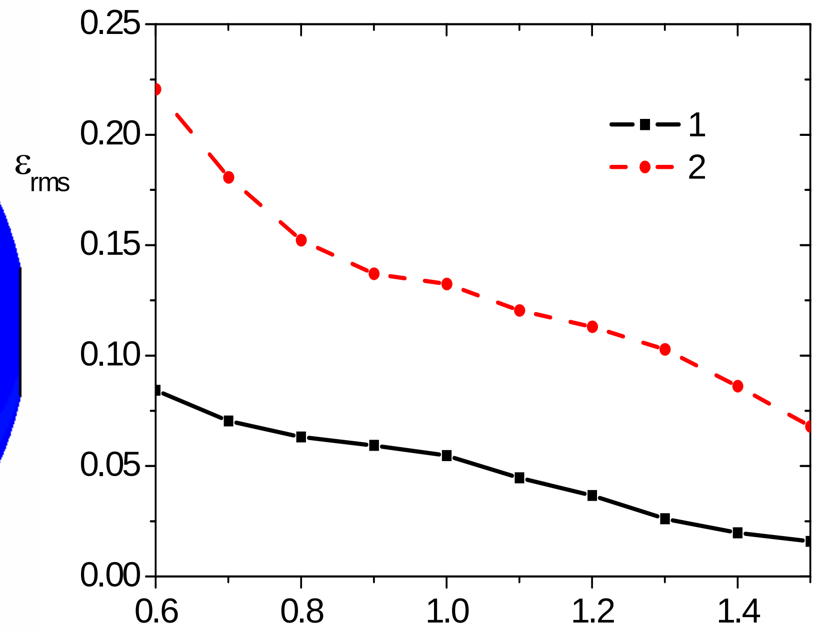
- Spherical copper box-converter with diameter ~1.3-2 mm. 6 laser entrance holes with diameter ~400-600 mcm. Inner surface was coved by gold layer.
- DT gas filled glass micro balloon with diameter ~0.3-1 mm. DT pressure 5-50 atm
- Laser pulse with typical FWHM 0.3-0.5 ns and energy 7-10 kJ

After upgrading ISKRA-5 on second harmonic the efficiency of absorption of laser beams was increased. But output laser energy of the facility was decreased to 2-3 kJ and illumination of focusing systemy was decreased too. As a result the nonuniformity of laser intensity at inner side of box-converter increased sharply. So the asymmetry of X-ray filed on the surface of glass balloon increased too.

Calculated nonuniformities of laser intensity and X-ray field



Position of laser spots at inner surface of spherical box

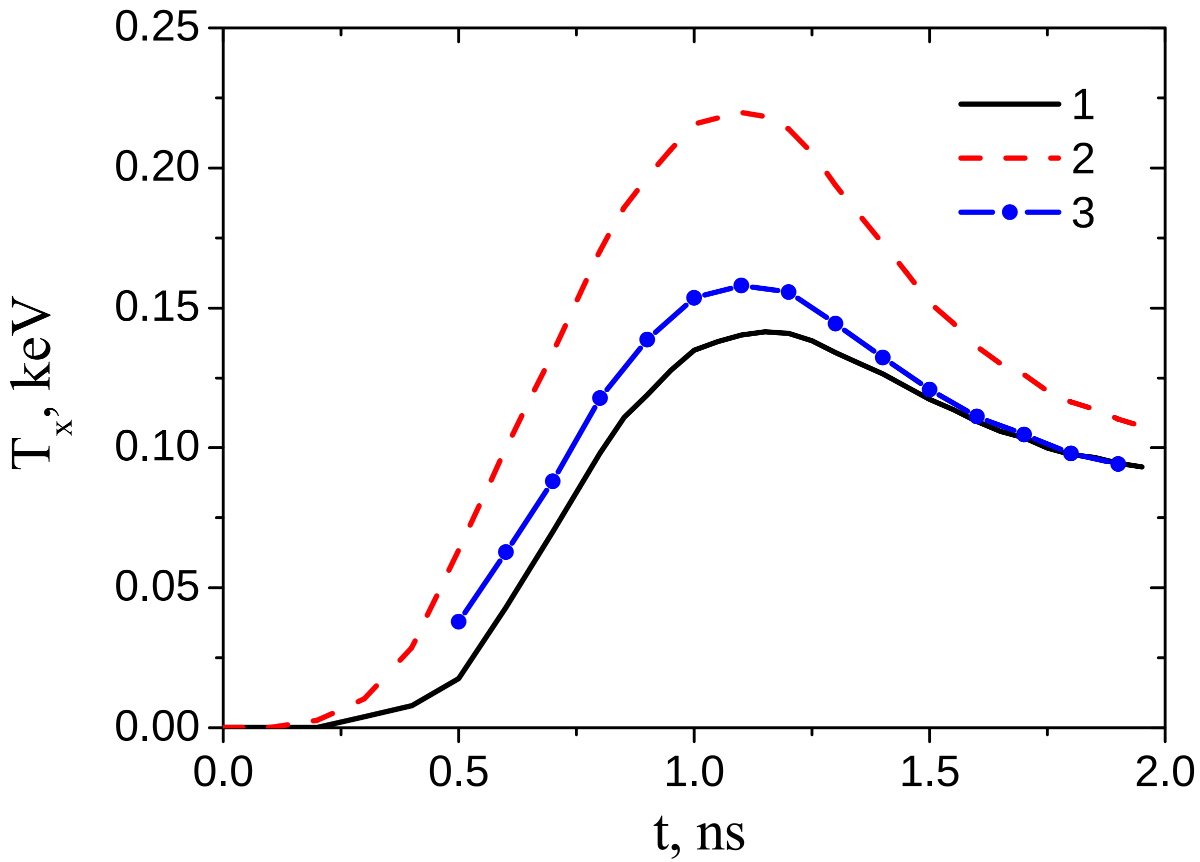


RMS dispersion of X-ray field nonuniformity on the surface of central capsule placed into box with the diameter ∅=1.3 mm for laser energy E_L=2 kJ.

1 – idealized case of laser beams with equal energy;

2 – calculation with 50% imbalance of beams energy

Calculated time dependence of the effective X-ray temperature in box-converter with diameter 1.3 mm



1 – non irradiated part of box surface;

2 – region of laser spots;

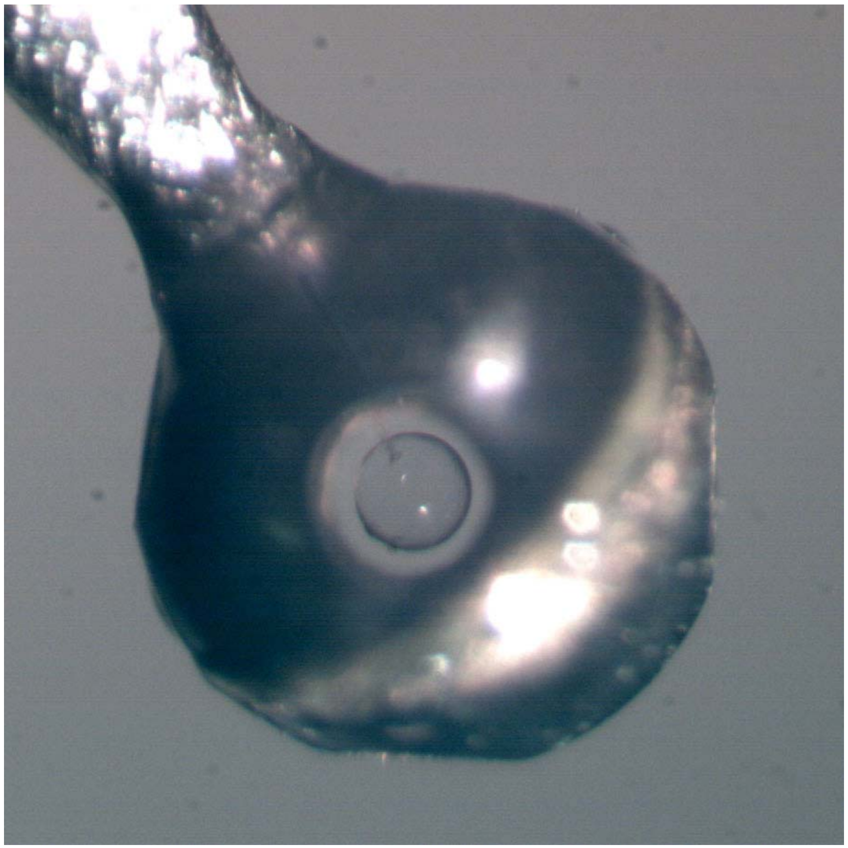
3 – glass micro balloon surface.

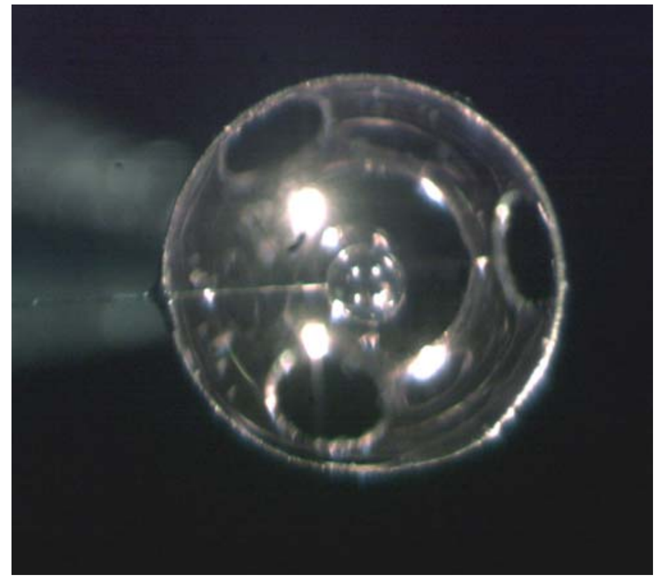
For box-converter with diameter 2 mm RMS dispersion is decreased about 2 times. But the maximum X-ray temperature doesn't exceed 130 eV

Parameters of laser pulse and central micro balloons in experiments

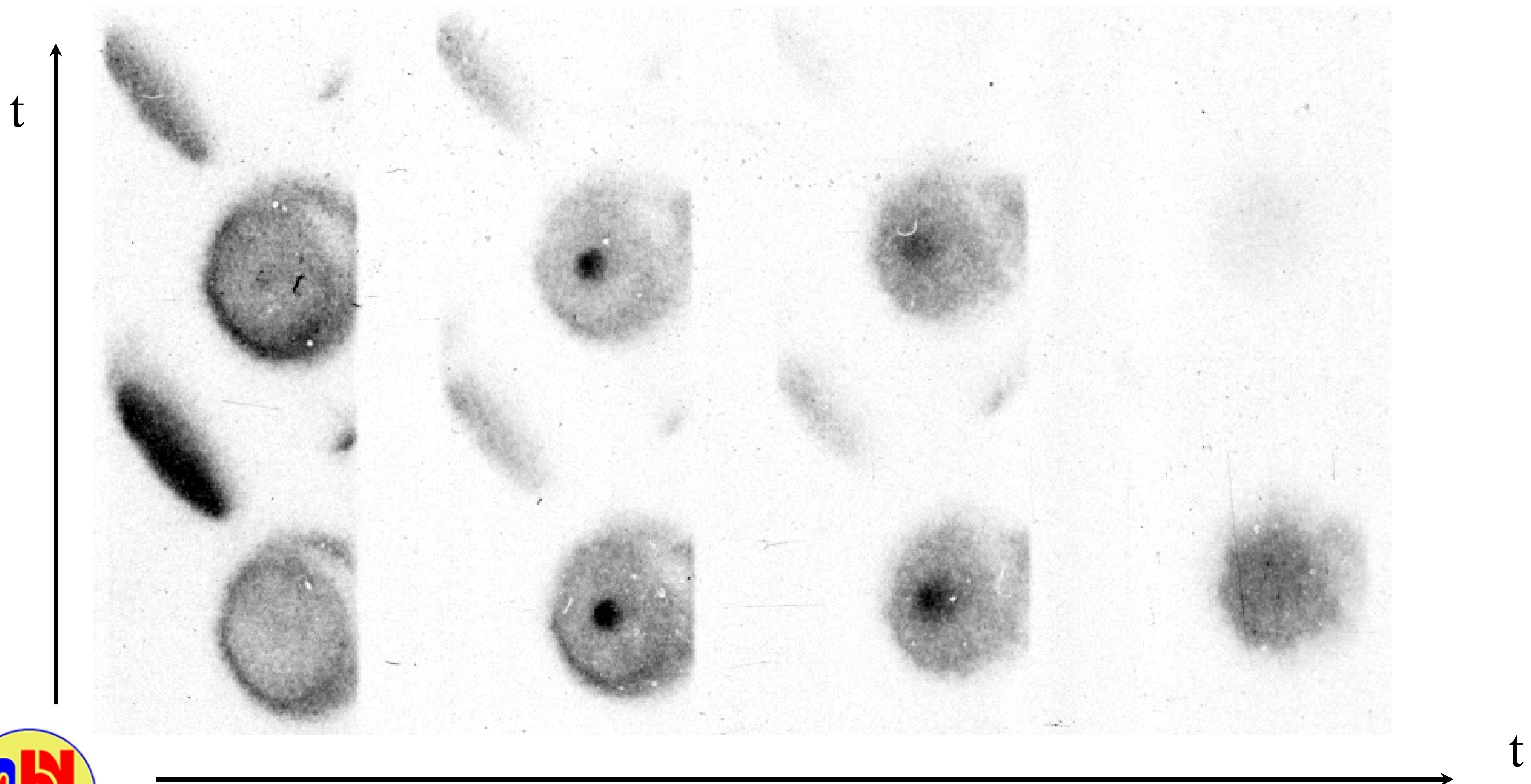
Exp #	Laser pulses		Central glass micro balloons		
	Laser energy E_L [J]	Pulse duration $\tau_{0.5}$ [ns]	diameter, [mcm]	Wall thickness, [mcm]	DT pressure, [atm]
1	2200	0.45	260	3.9	27
2	1980	0.75	267	4.4	16
3	2440	0.58	268	3.8	16

Image of the target used in experiment #2



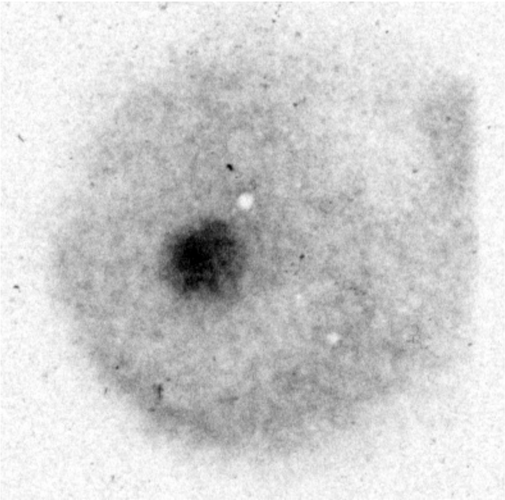


Measurement of the compression glass micro balloon for experiment #2 with help of multi frame pinhole camera

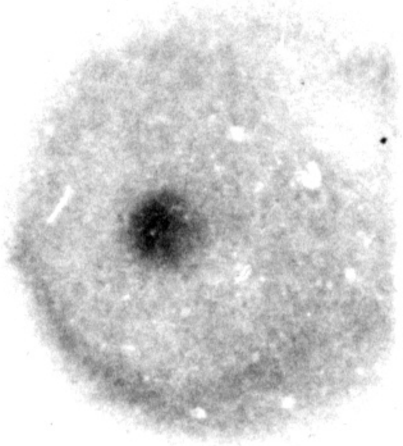


Different frames of the central sphere near the time of maximum compression

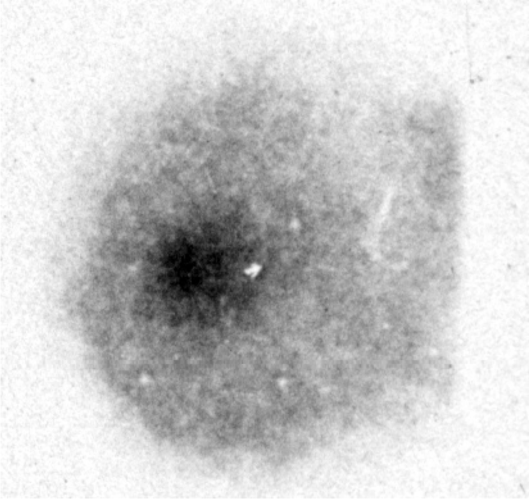
frame 0.5 ns



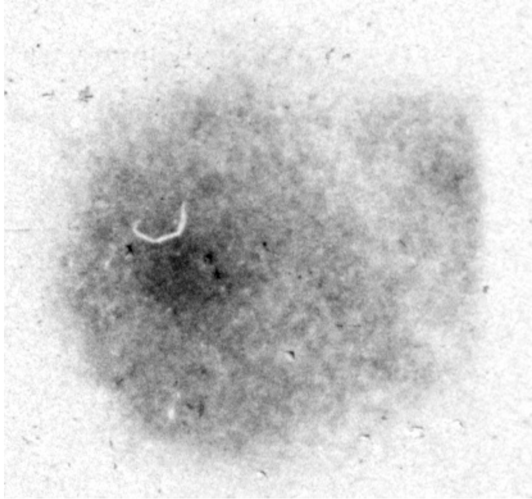
frame 0.6 ns



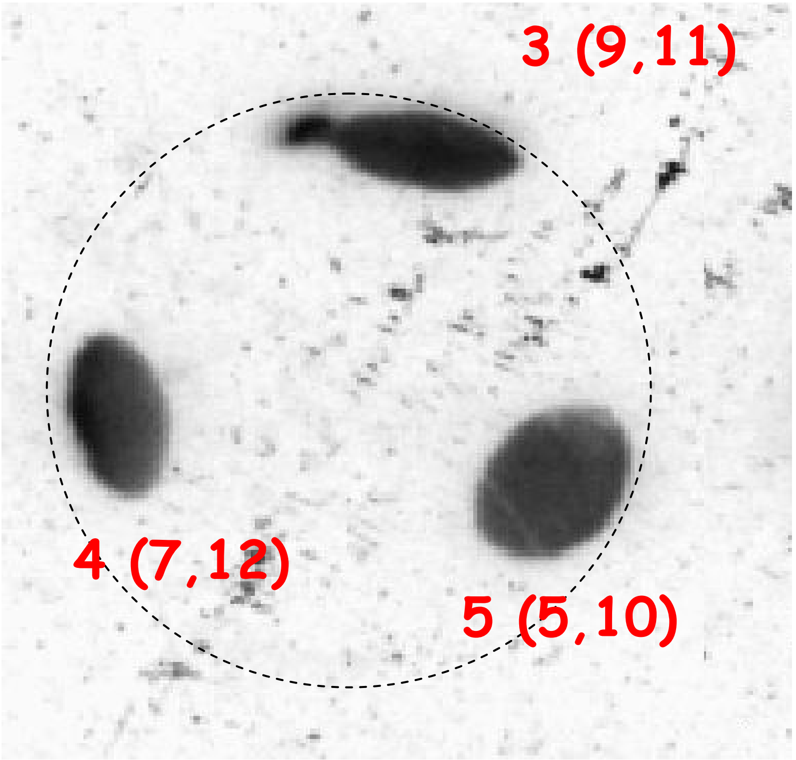
frame 0.7 ns

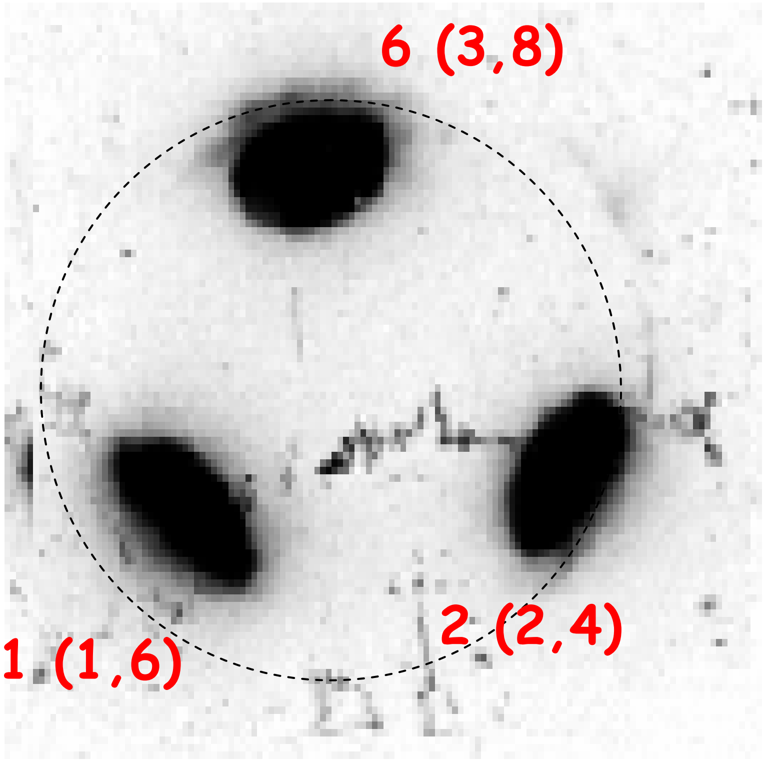


frame 0.8 ns

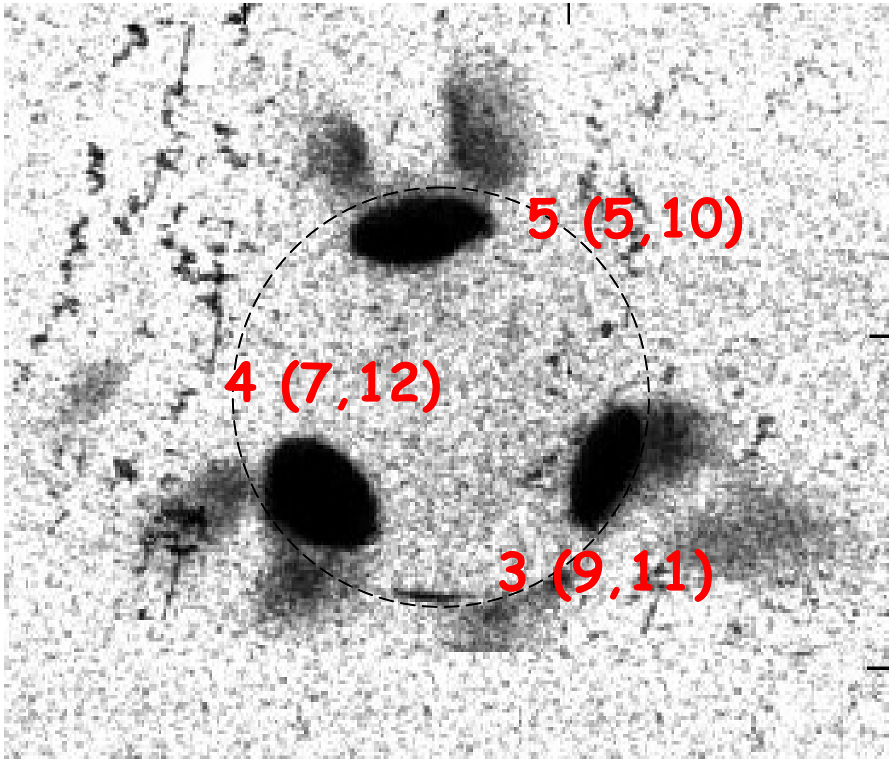


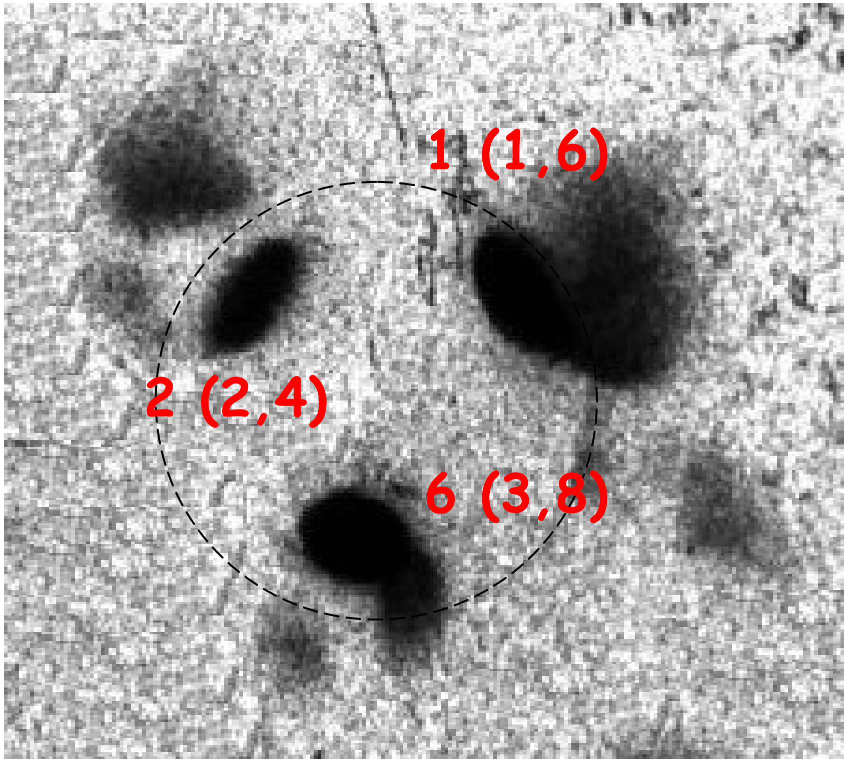
Pinhole images of the target obtained in experiment #1



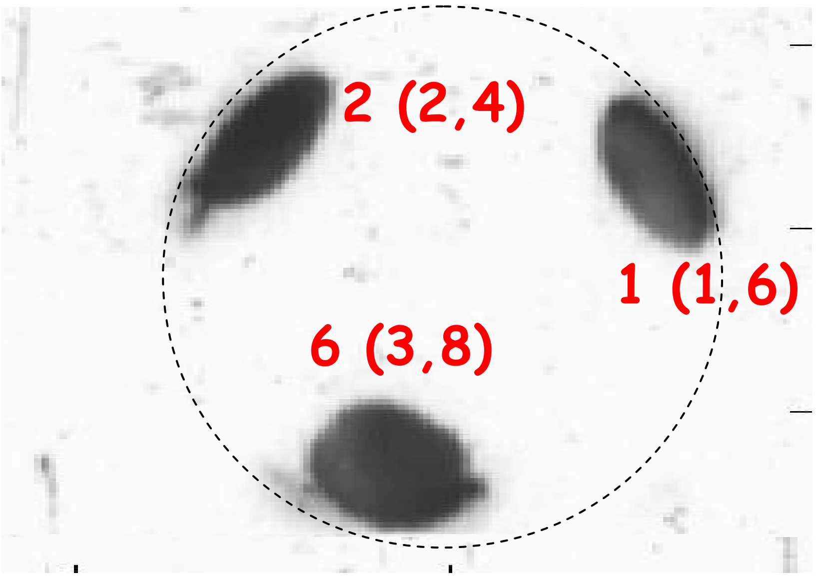


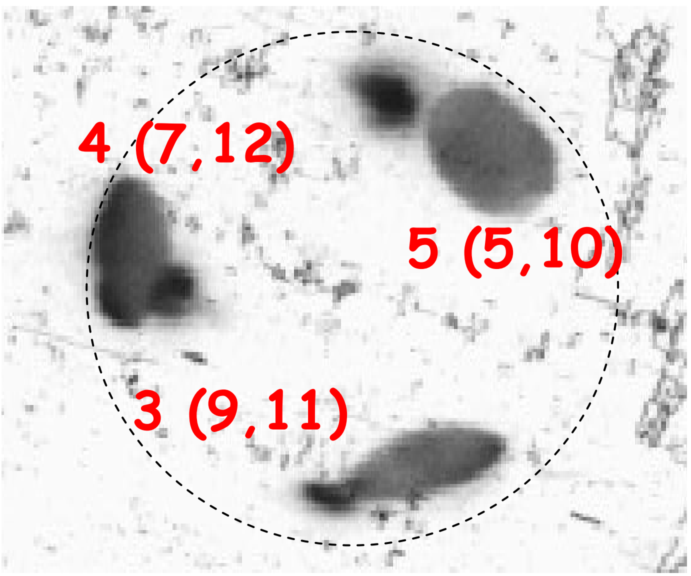
Pinhole images of the target obtained in experiment #2





Pinhole images of the target obtained in experiment #3





Neutron yield measured in experiments by different diagnistics

Exp #	In activation	MDM1 detector	MDM2 detector	Ion temperature T_i, keV
1	7.10^8	saturation	8.10^8	1.1±0.4
2	4.10^8	saturation	4.10^8	1.1*
3	3.10^8	saturation	3.10^8	1.3*

Physical processes considering in calculation using 1D code SNDP and 2D code MIMOZA-ND

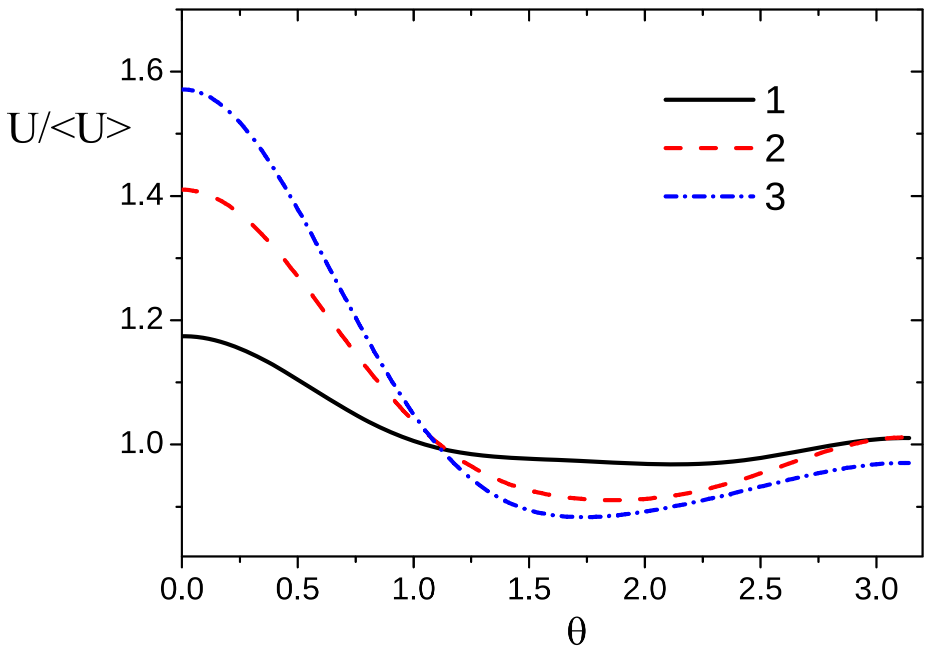
- Laser absorption
- 2 temperature non LTE gas dynamic with electron and ion heat transfer
- Spectral diffusion of non LTE X-ray
- Ionization kinetic of non LTE and non stationary plasma with help of average ion atom approximation to calculate different transport coefficient
- Average ion EOS of multi component plasma

Results of 1D calculation for experimental condition obtained using SNDP code

#	E_L, kJ	$\tau_{0.5}$, ns	N_{calc},	N_{exp}
1	2.2	0.45	$8.6 \cdot 10^8$	$7.5 \cdot 10^8$
2	1.98	0.75	$4 \cdot 10^8$	$4 \cdot 10^8$
3	2.44	0.58	$1.1 \cdot 10^9$	$3 \cdot 10^8$

2D code MIMOZA-ND calculations of experiment #3

Angle dependences of X-ray filed perturbations on surface of central capsule used in 2D calculations

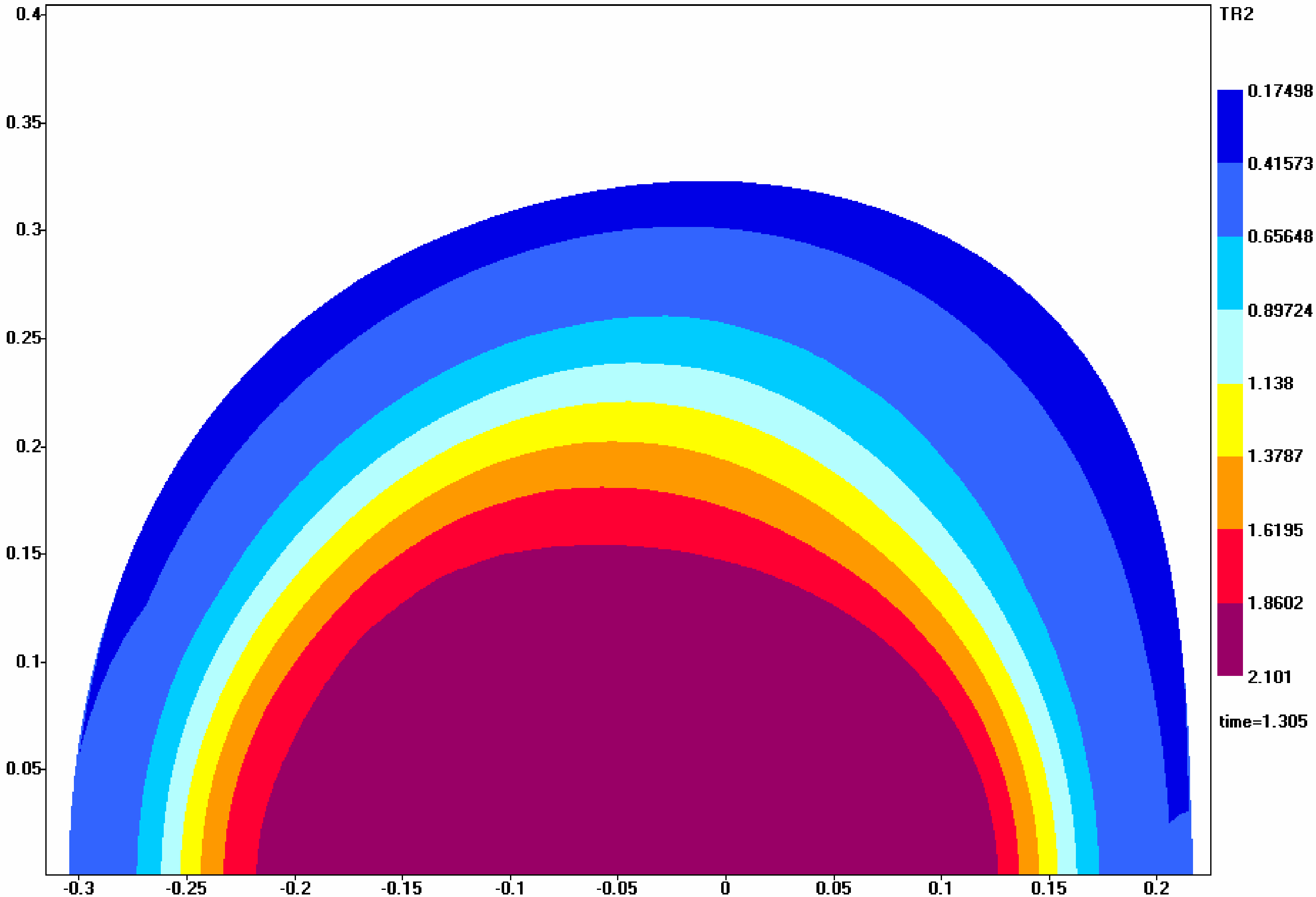


1 – case “full” of nominal laser energy E_L=2.44 kJ;

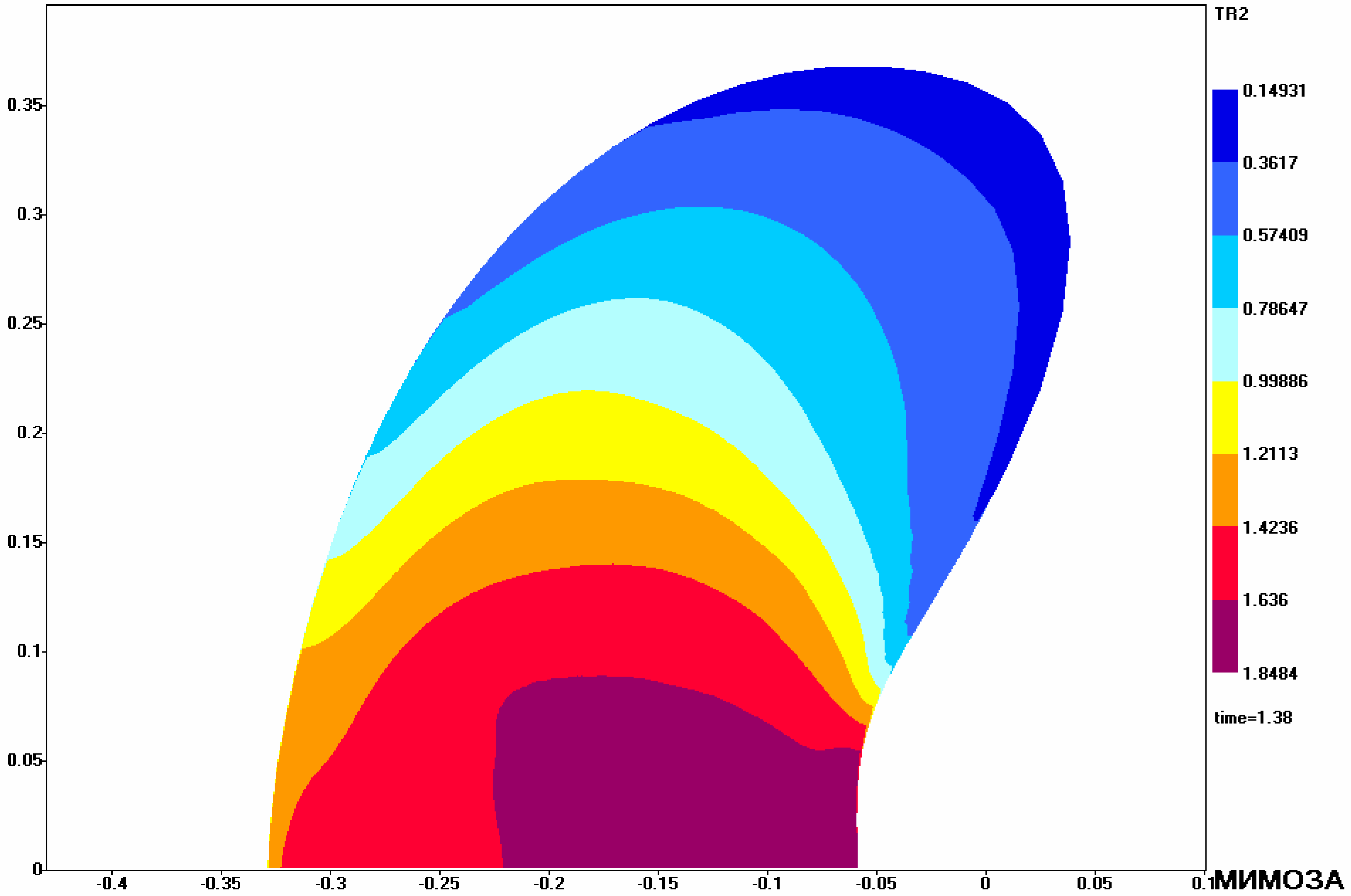
2 - case “max” E_L=1.96 kJ (beams ##7,9,10 were not entered);

3 - case “min” E_L=1.8 kJ (beams ##5,11,12 were not entered)

DT gas ion temperature distribution obtained in calculation of experiment #3 at the moment of neutron generation with nominal energy (Full)



DT gas ion temperature distribution obtained in calculation of experiment #3 at the moment of neutron generation with minimal energy (Min)



Results of 2D calculations

$E_{exp}=3\cdot10^8$

	$E_L=2.44$ kJ	$E_L^{max}=1.96$ kJ	$E_L^{min}=1.8$ kJ
1D	$1.04\cdot10^9$	$6.91\cdot10^8$	$5.21\cdot10^8$
2D	$7.48\cdot10^8$	$3.22\cdot10^8$	$1.64\cdot10^8$

S.A.Belkov