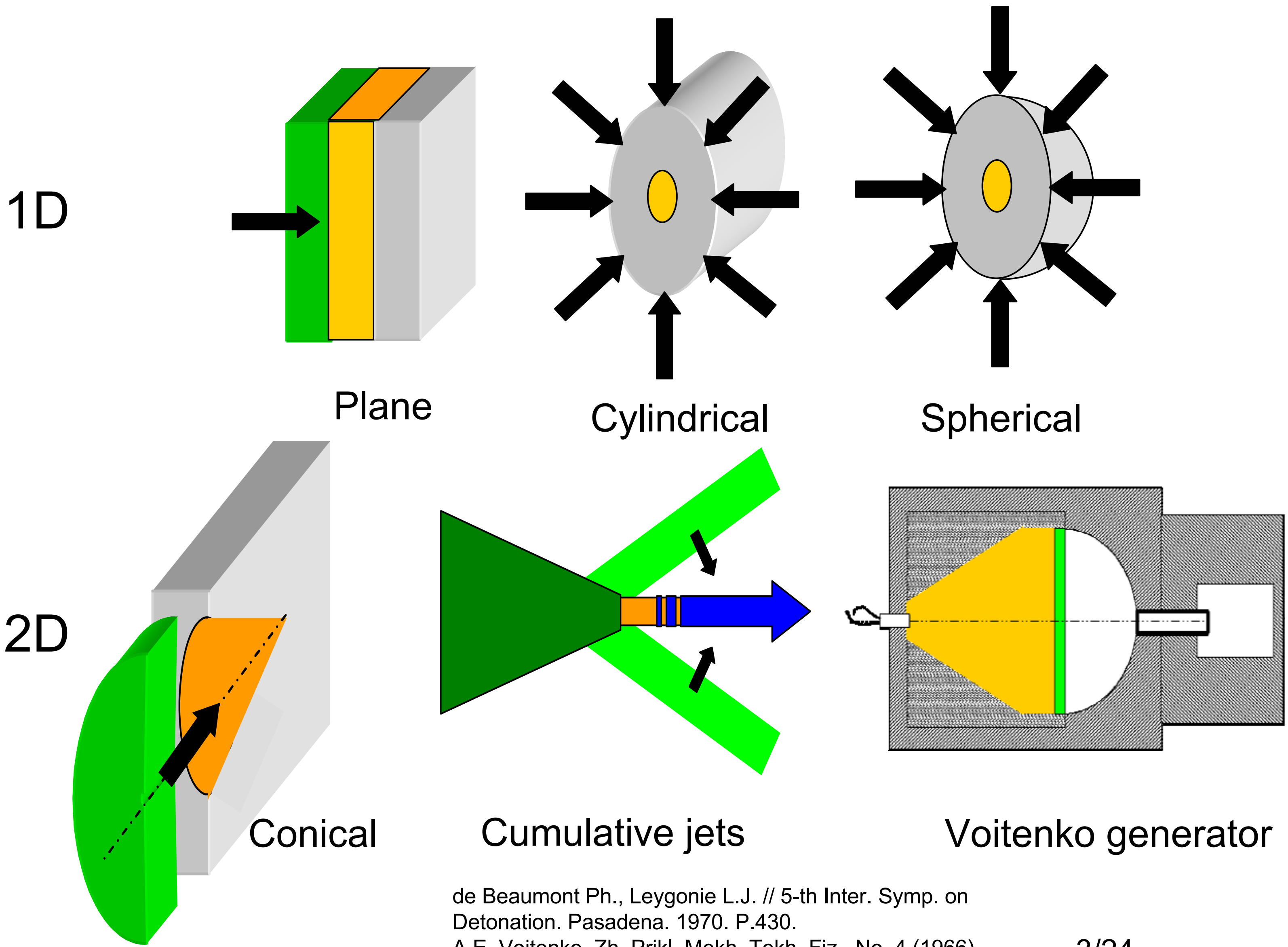
Stimulated Mach configuration created by Heavy Ion Beam as a tool for experimental research.

Shutov A.V., Zharkov A.P.,
shutov@ficp.ac.ru
IPCP, Chernogolovka, RAS, Russia
Tahir N.A.
GSI, Darmstadt, Germany

Outlook

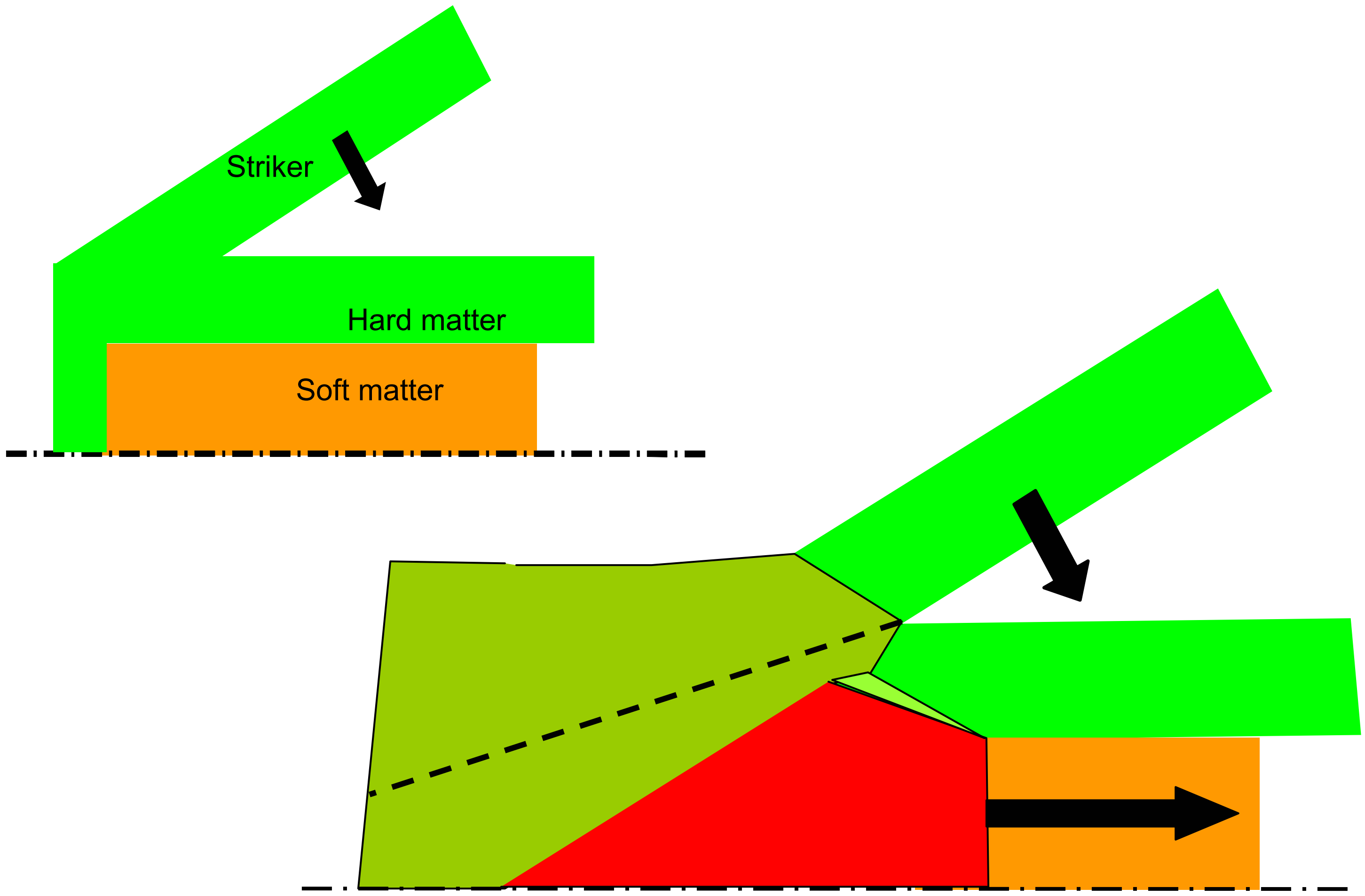
- Dynamic schemes of compressed state generation
- Generation of Stimulated Mach Configurations (SMC)
- SMC generation by IHOB
- Comparison SMC with LAPLAS

Dynamic schemes of compressed state generation



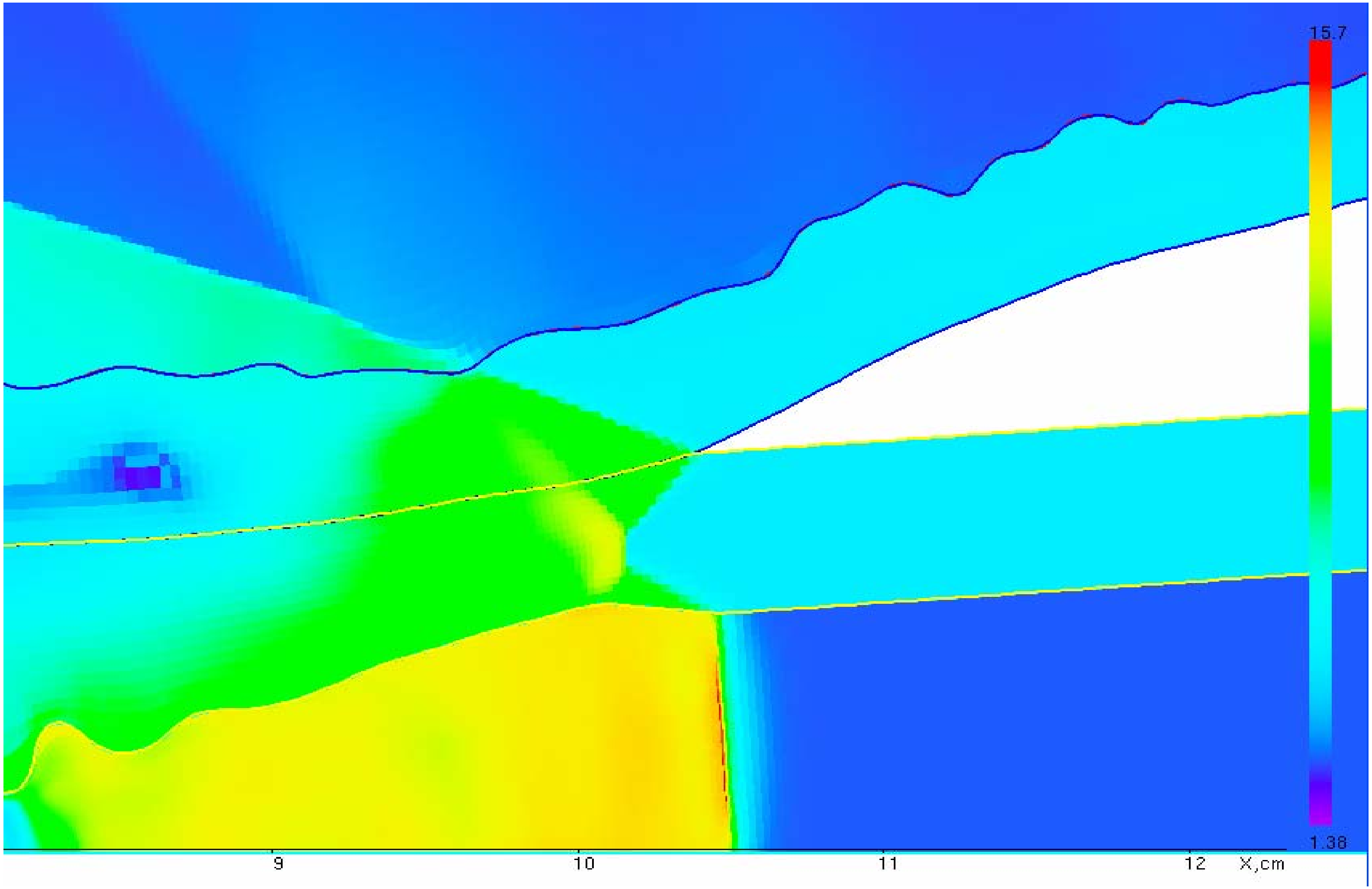
de Beaumont Ph., Leygonie L.J. // 5-th Inter. Symp. on Detonation. Pasadena. 1970. P.430.
A.E. Voitenko, Zh. Prikl. Mekh. Tekh. Fiz., No. 4 (1966)

Generation of Stimulated Mach Configurations (SMC)

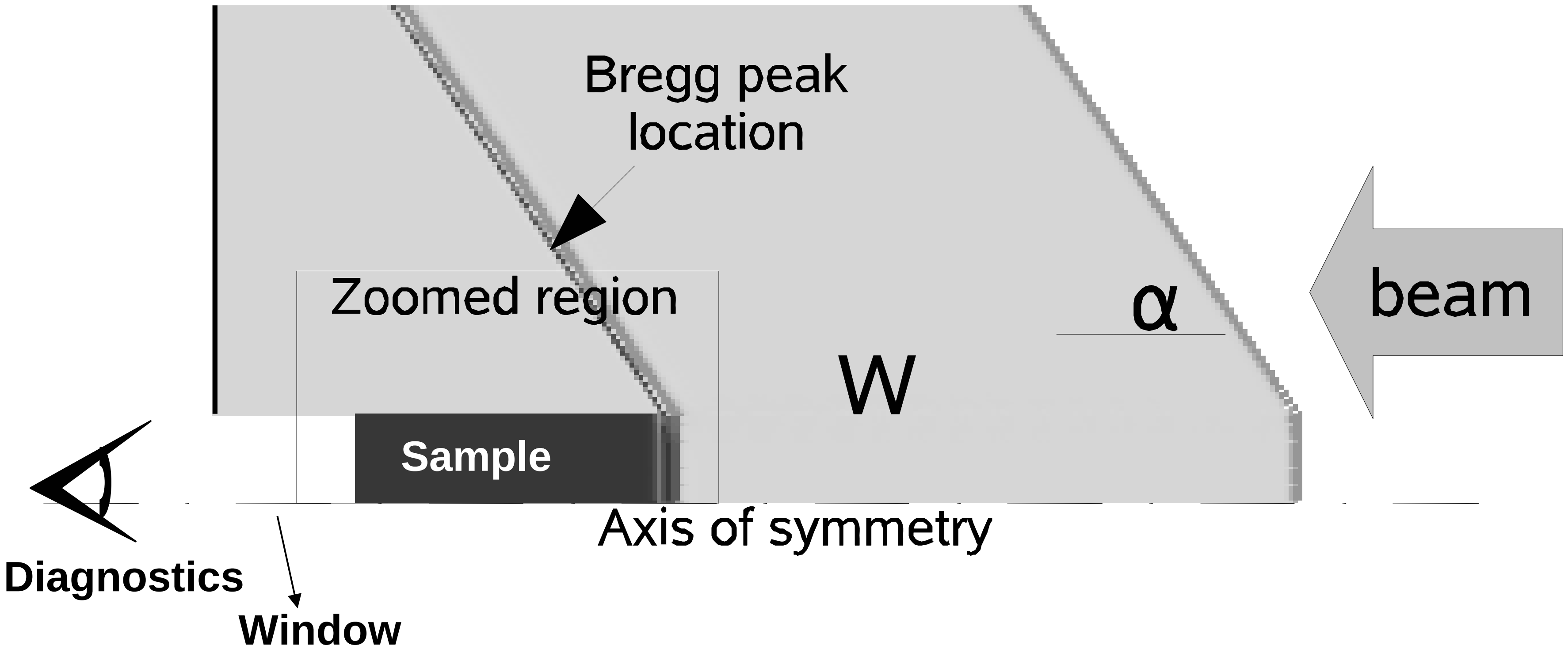


A.P.Zharkov, B.P.Kryukov, A.V.Shutov Double Mach reflection effect usage for generation of high power shock waves in metals // Physics of extreme states of matter -2004 / ed. by V.E.Fortov et al., Chernogolovka, IPCP RAS, 2004, p. 110-112 (in Russian)

Simulation of HE Zharkov's generator.

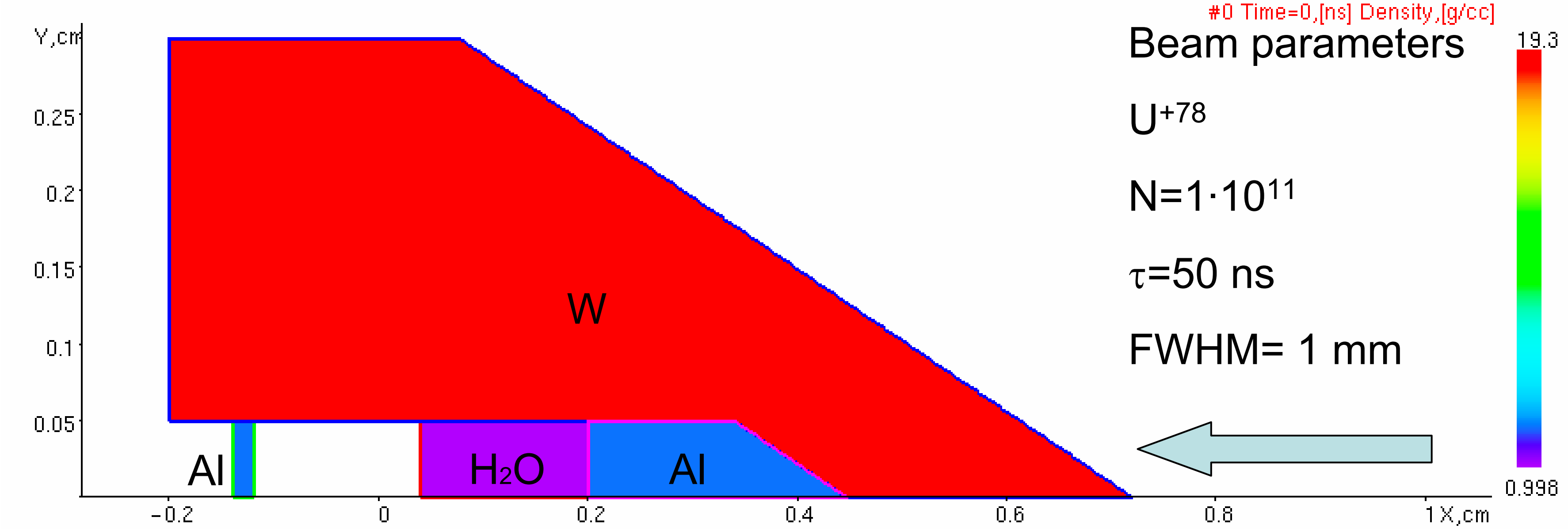


Generation of SMC by heavy ion beam



A. Shutov, A.P. Zharkov, N.A. Tahir, **Numerical simulation of Mach wave configurations generated by intense heavy ion beam as a scheme for investigation extreme states of matter // Weyrich, Karin (Ed.): High Energy Density Physics with Intense Ion and Laser Beams: Annual Report 2007, TH-17,p.54, GSI Report 2008-02**

Target fitted for SMC



Beam parameters

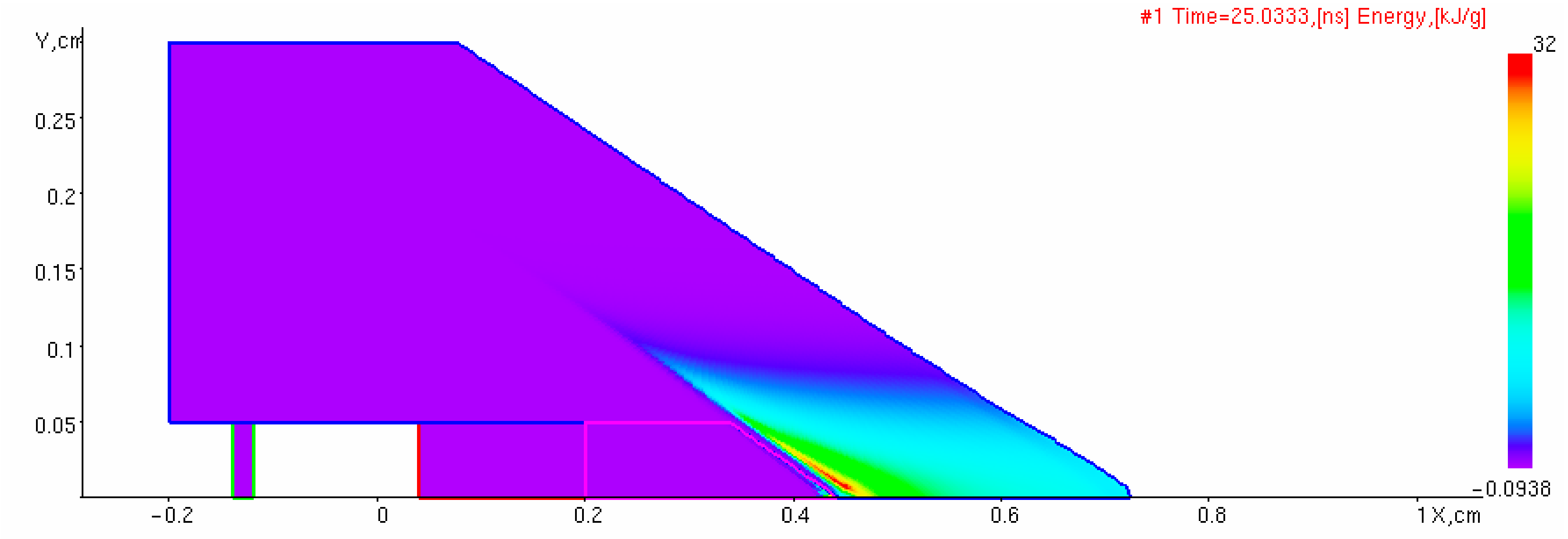
U^{+78}

$N=1\cdot10^{11}$

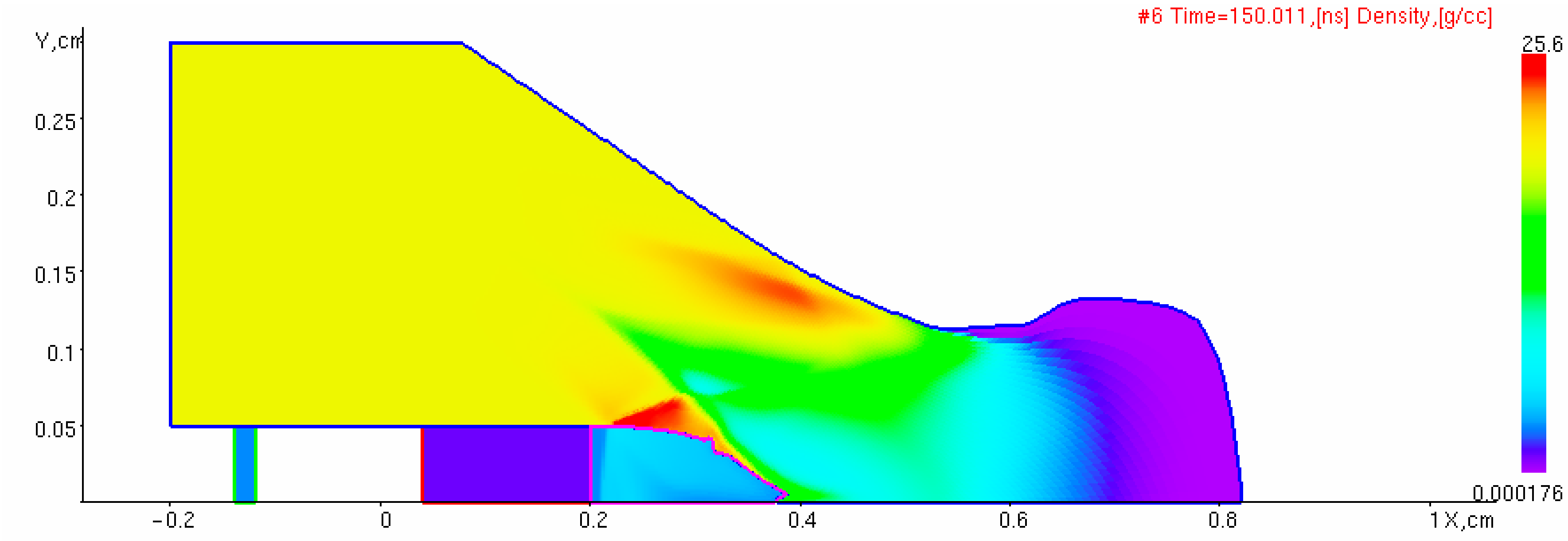
τ=50 ns

FWHM= 1 mm

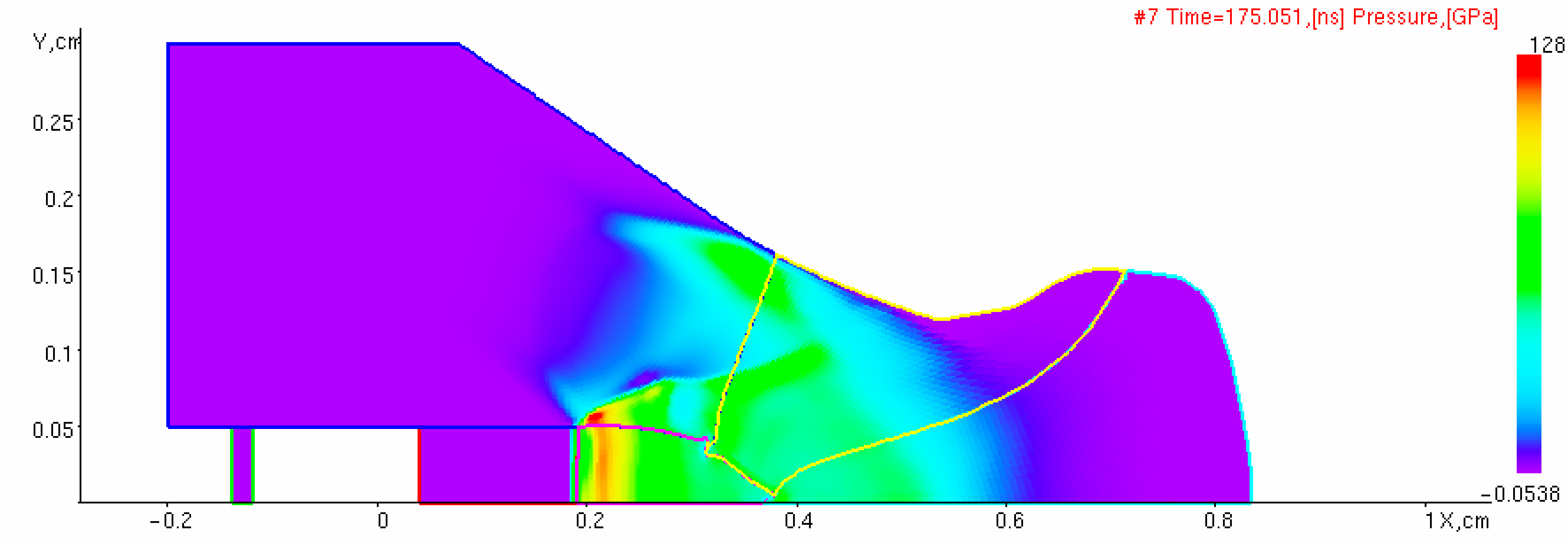
Initial stage 25 ns



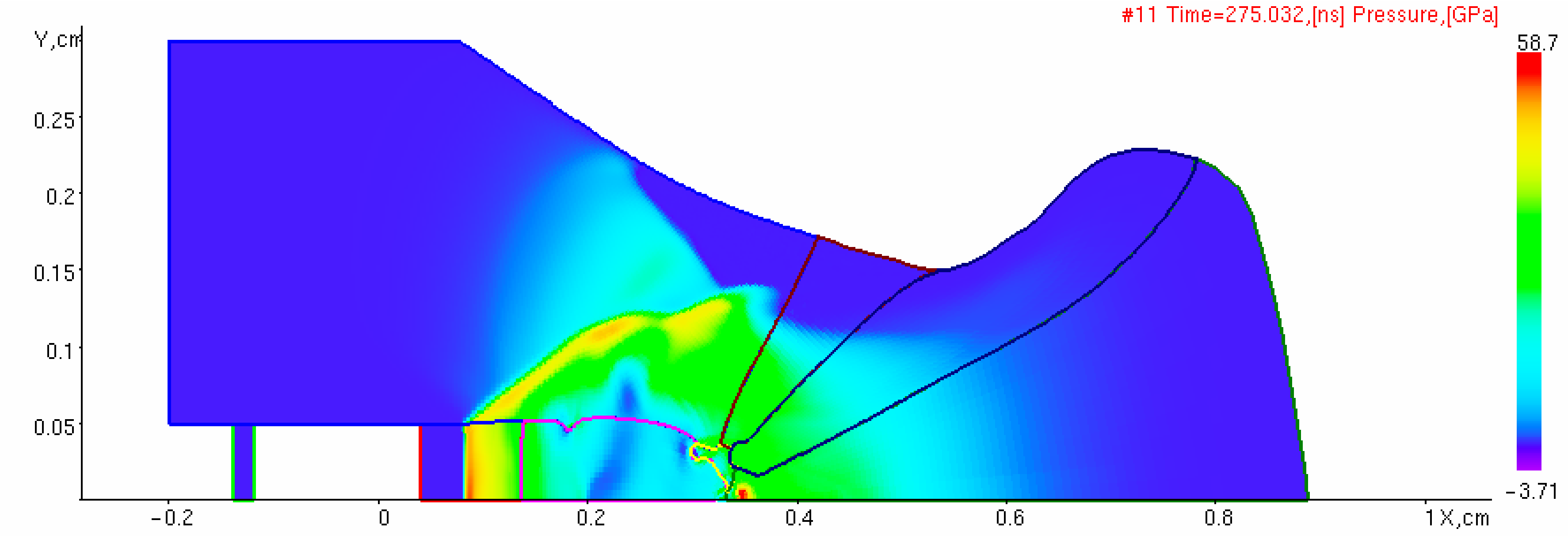
Generation of Mach configuration in aluminum (150 ns)



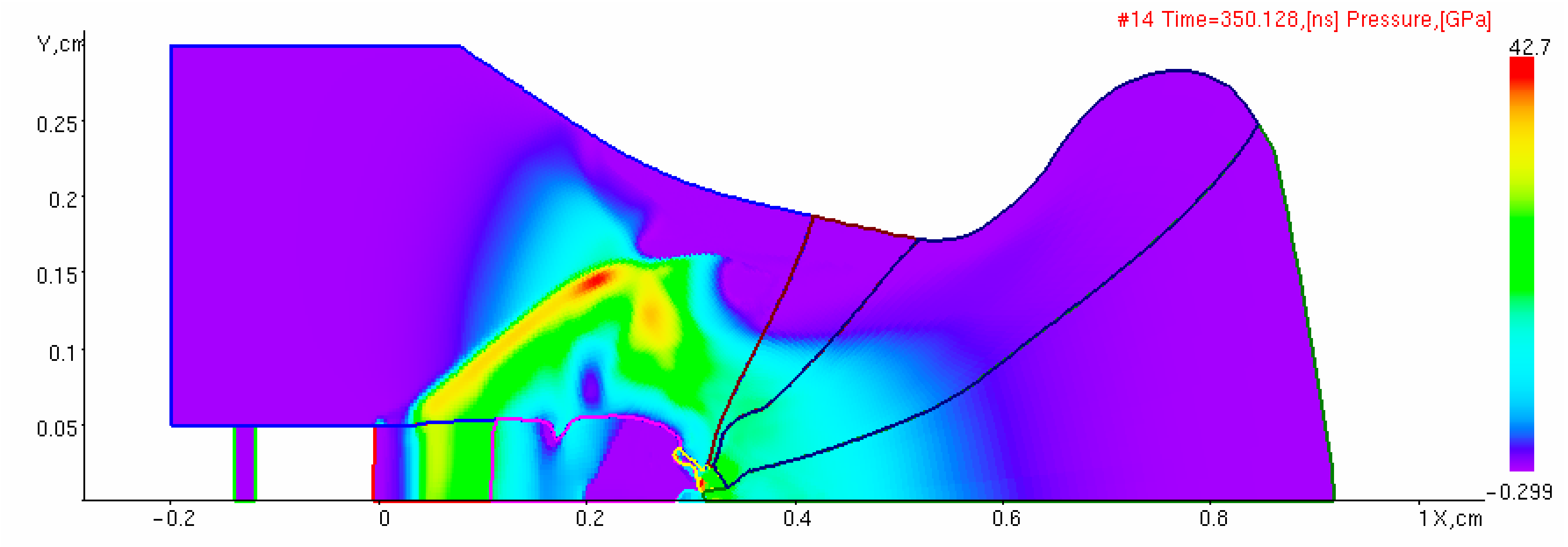
Transition of the Mach stem from aluminum to water (175 нс)



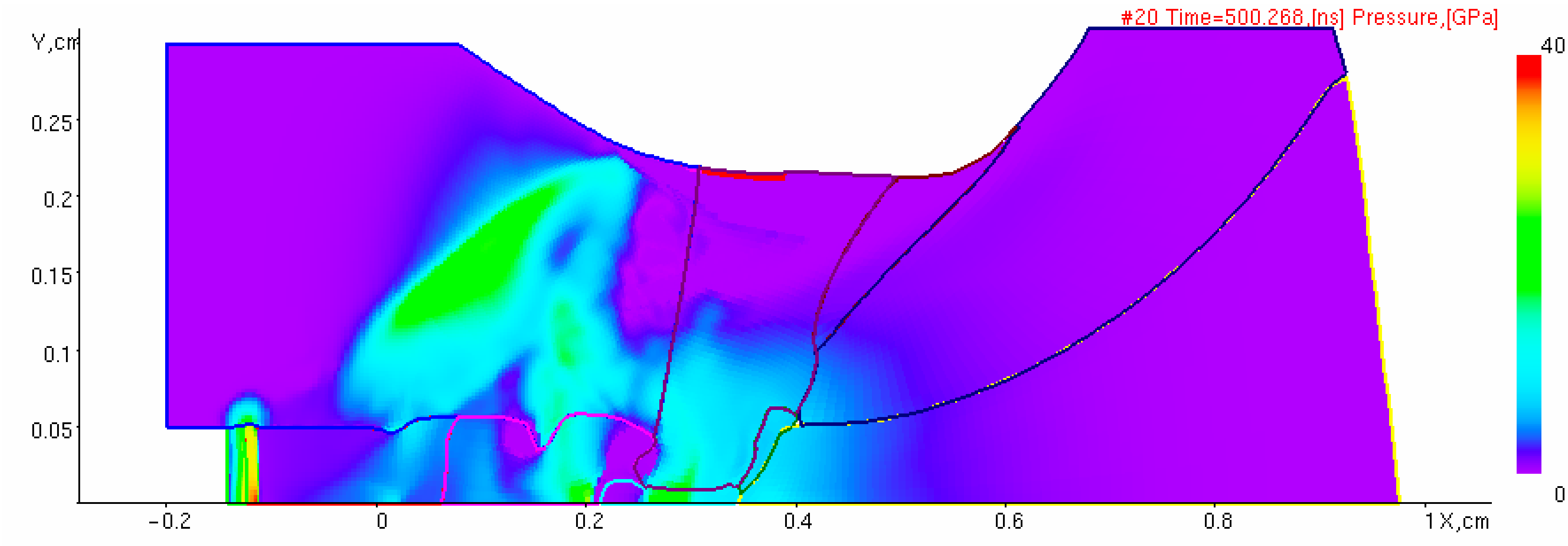
Propagation of Shock wave in water (275 ns)



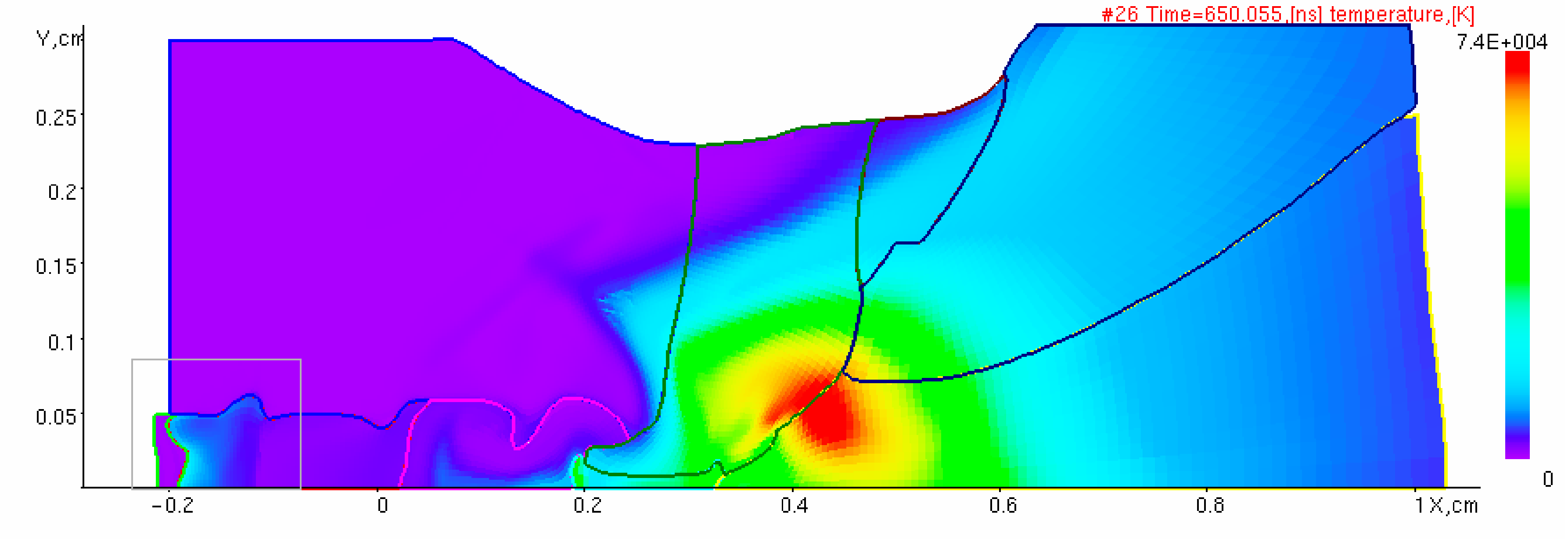
Expansion of water into vacuum (275 ns)



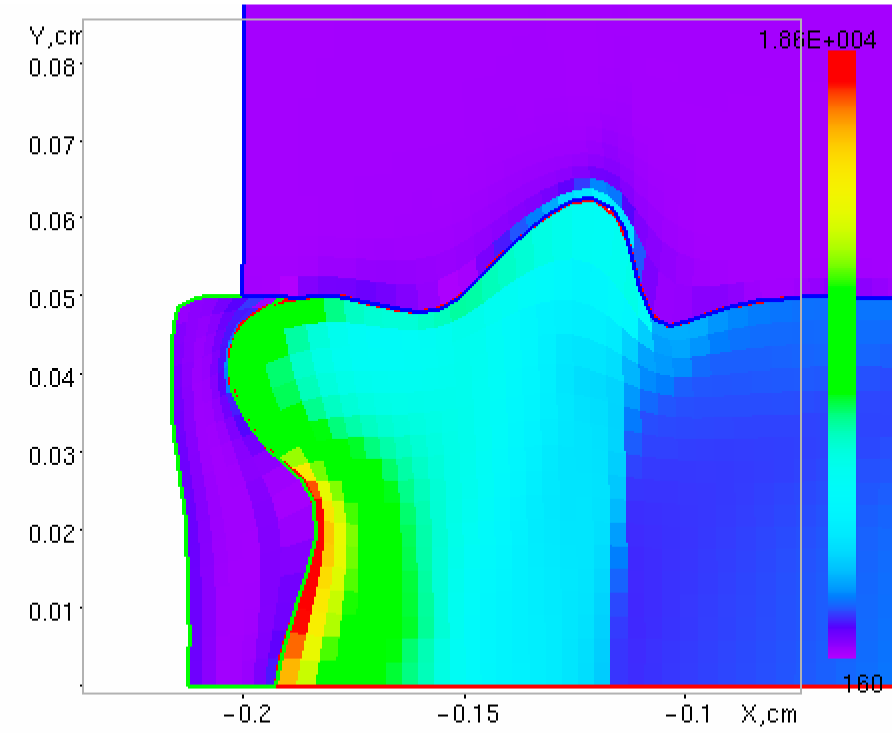
Acceleration of aluminum foil by water vapors (500 ns)



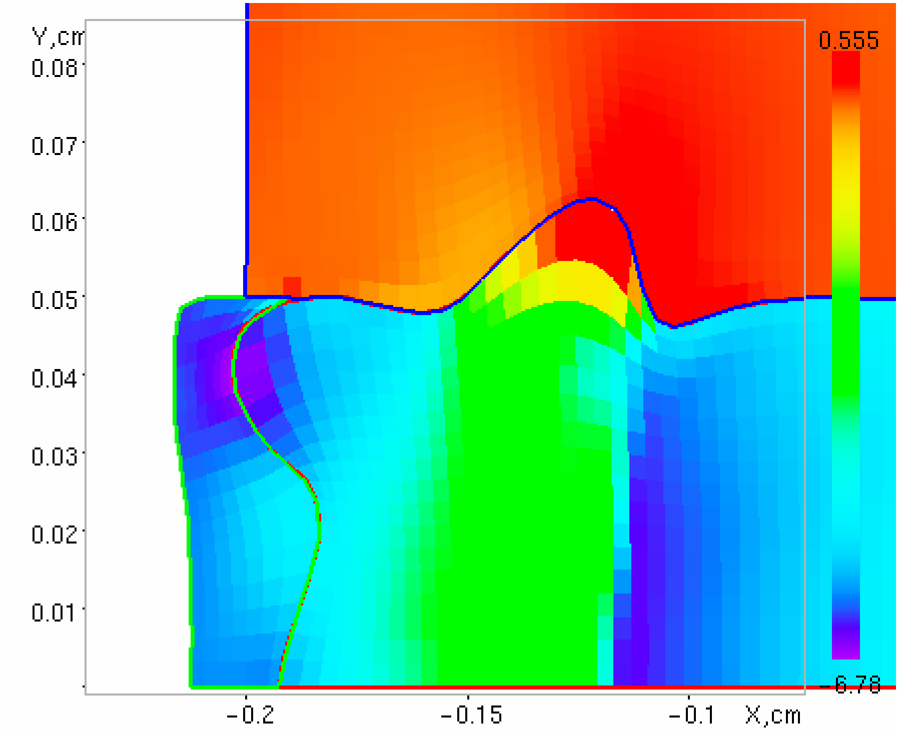
Temperature distribution (650ns)



Parameters about aluminum foil

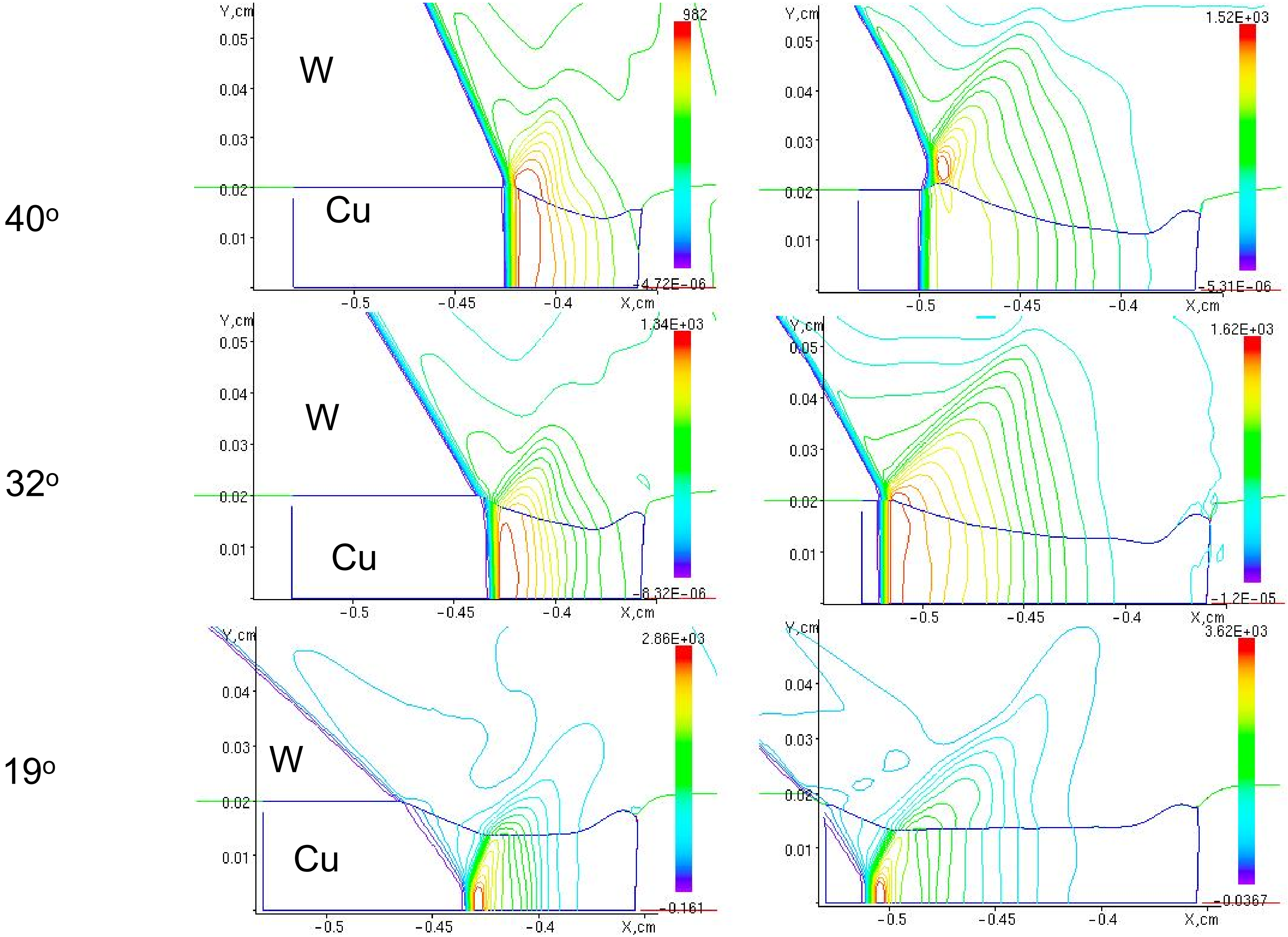


Temperature ~ 400 k

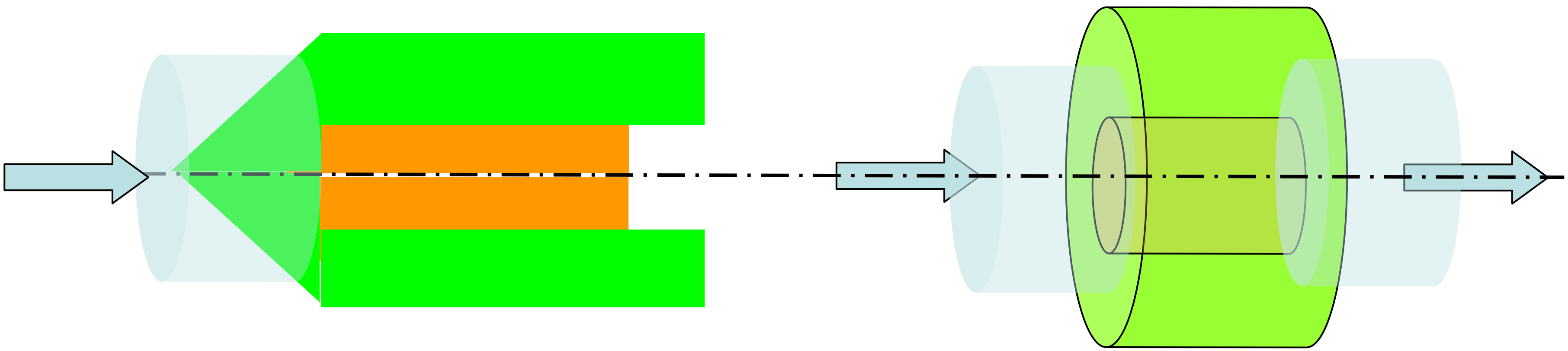


Velocity X ~ 6.8 km/s

Evolution of mach configurations



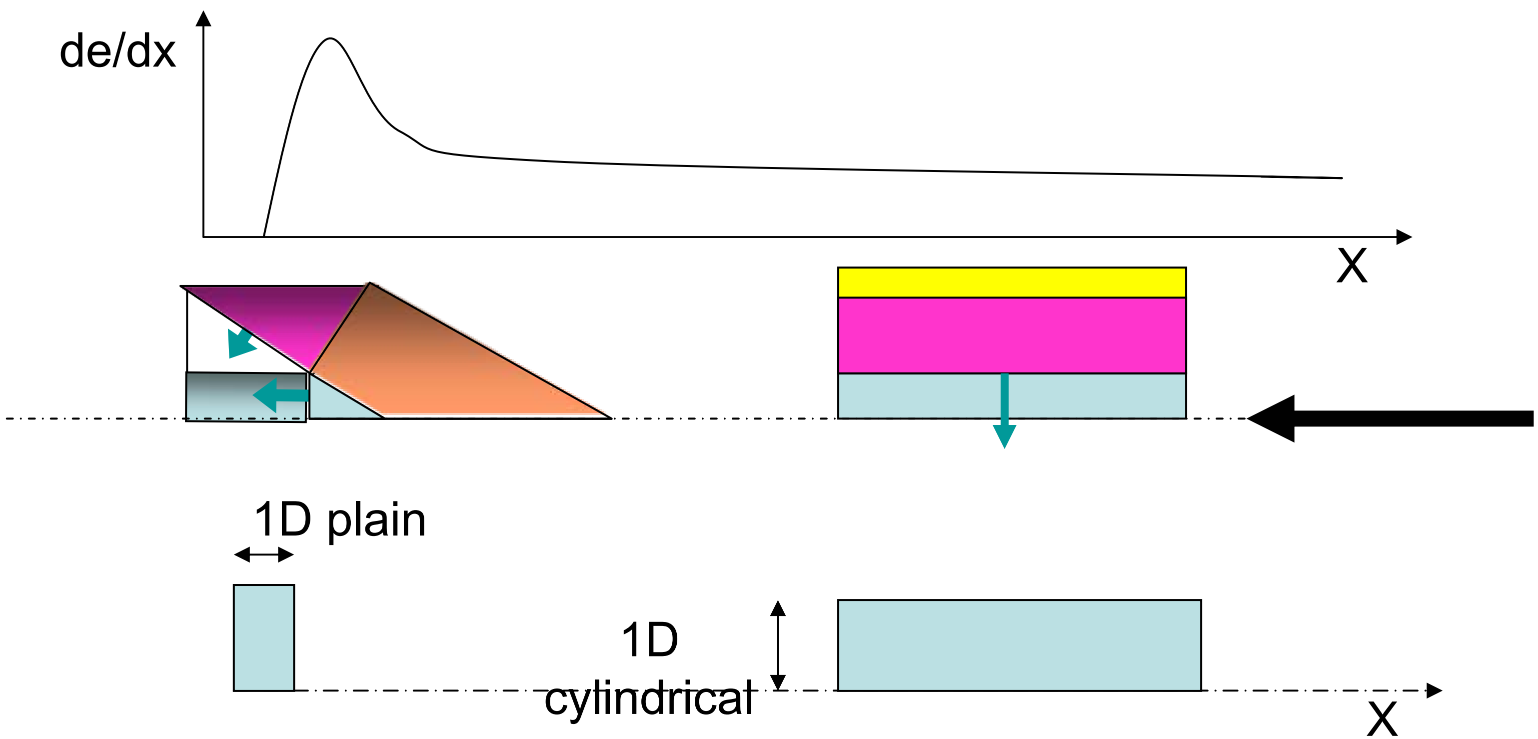
SMC & LAPLAS



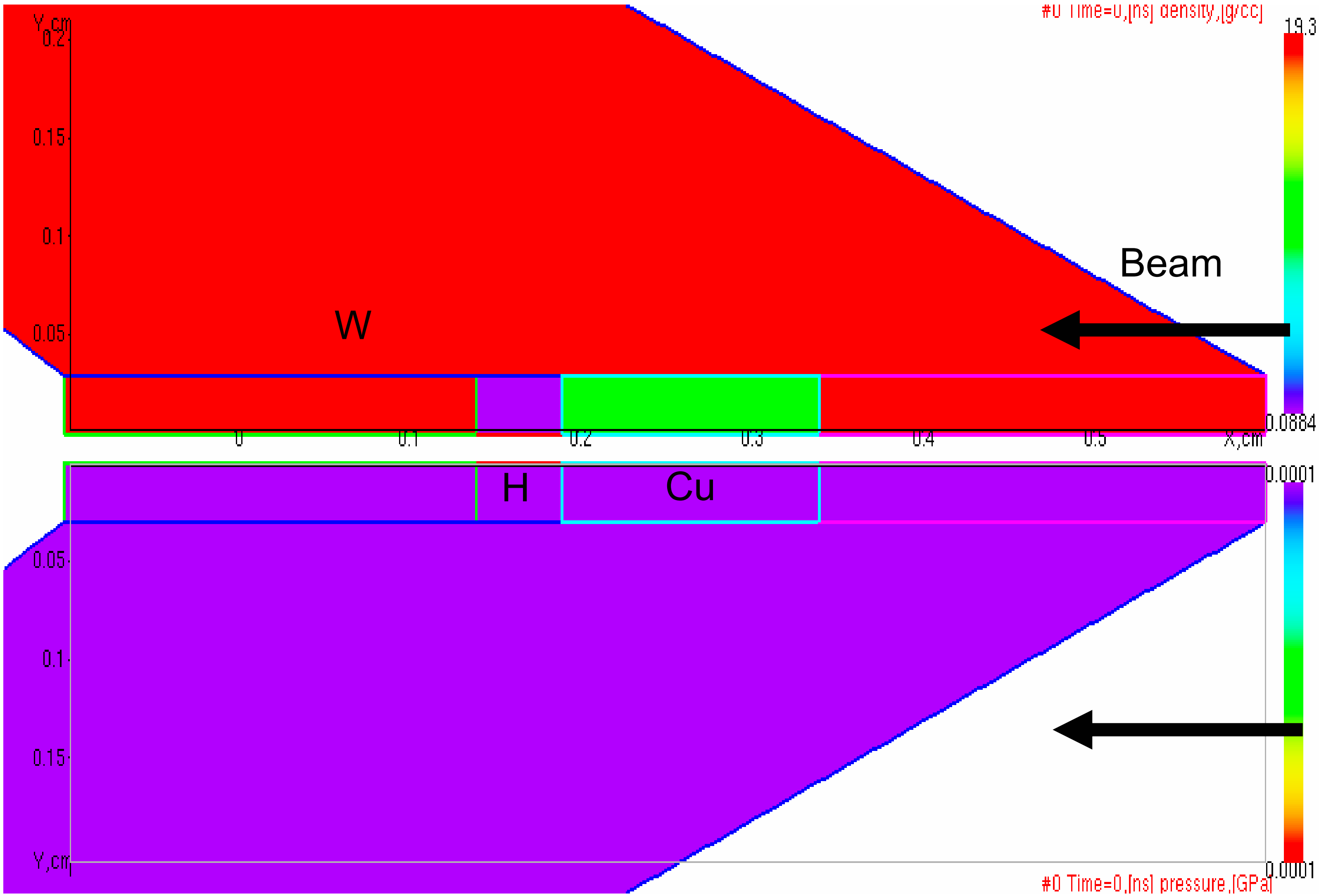
The common features

- Both use circular ion beam
- Convergence of hydrodynamic flow to the axis is used
- The aim is matter in strongly compressed state.

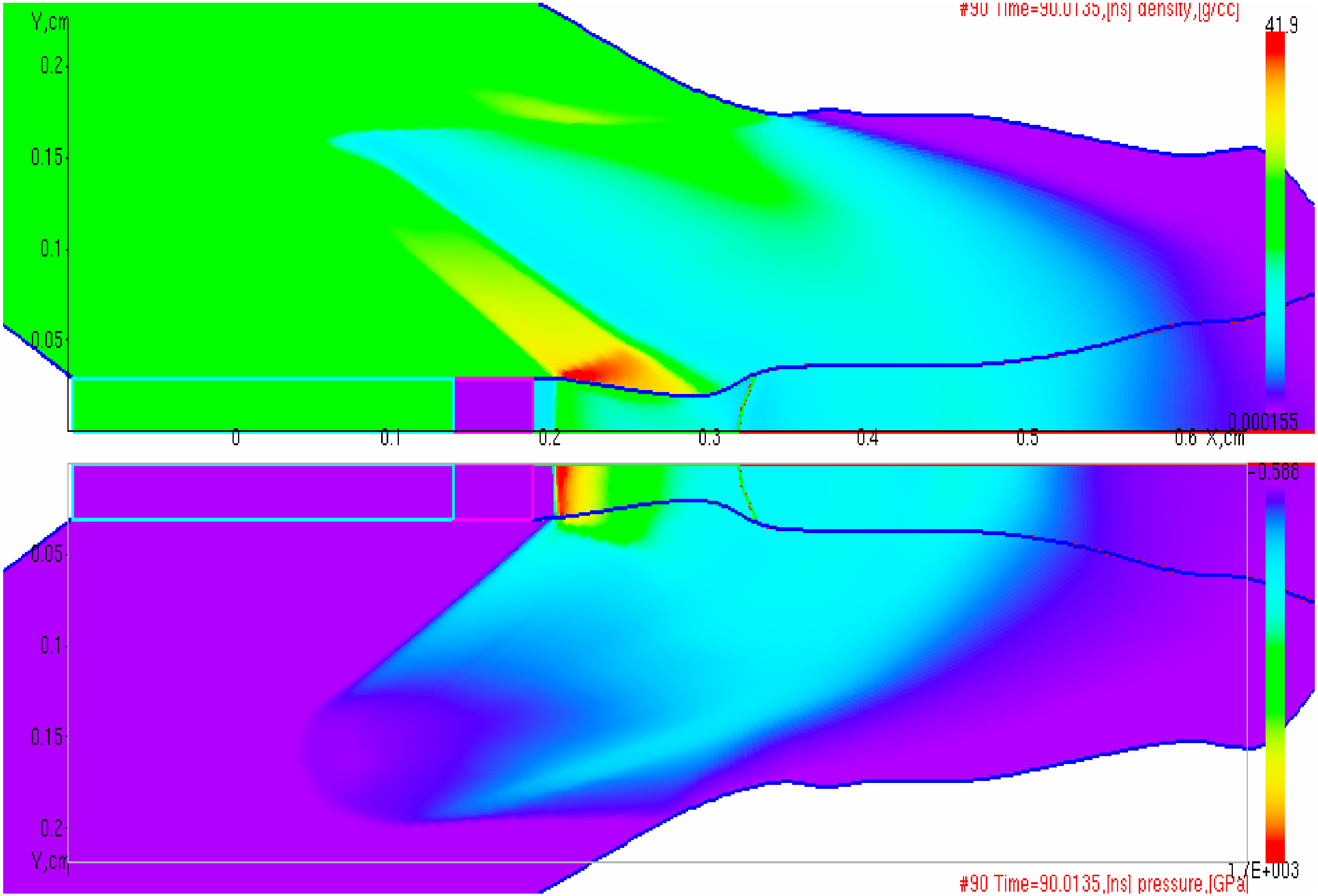
SMC	LAPLAS
➢ Bragg peak	➢ Constant stopping power
➢ 2D cylindrical symmetry for energy cumulation 1D plain for measurements	➢ 1D cylindrical symmetry
➢ Disk	➢ Wire



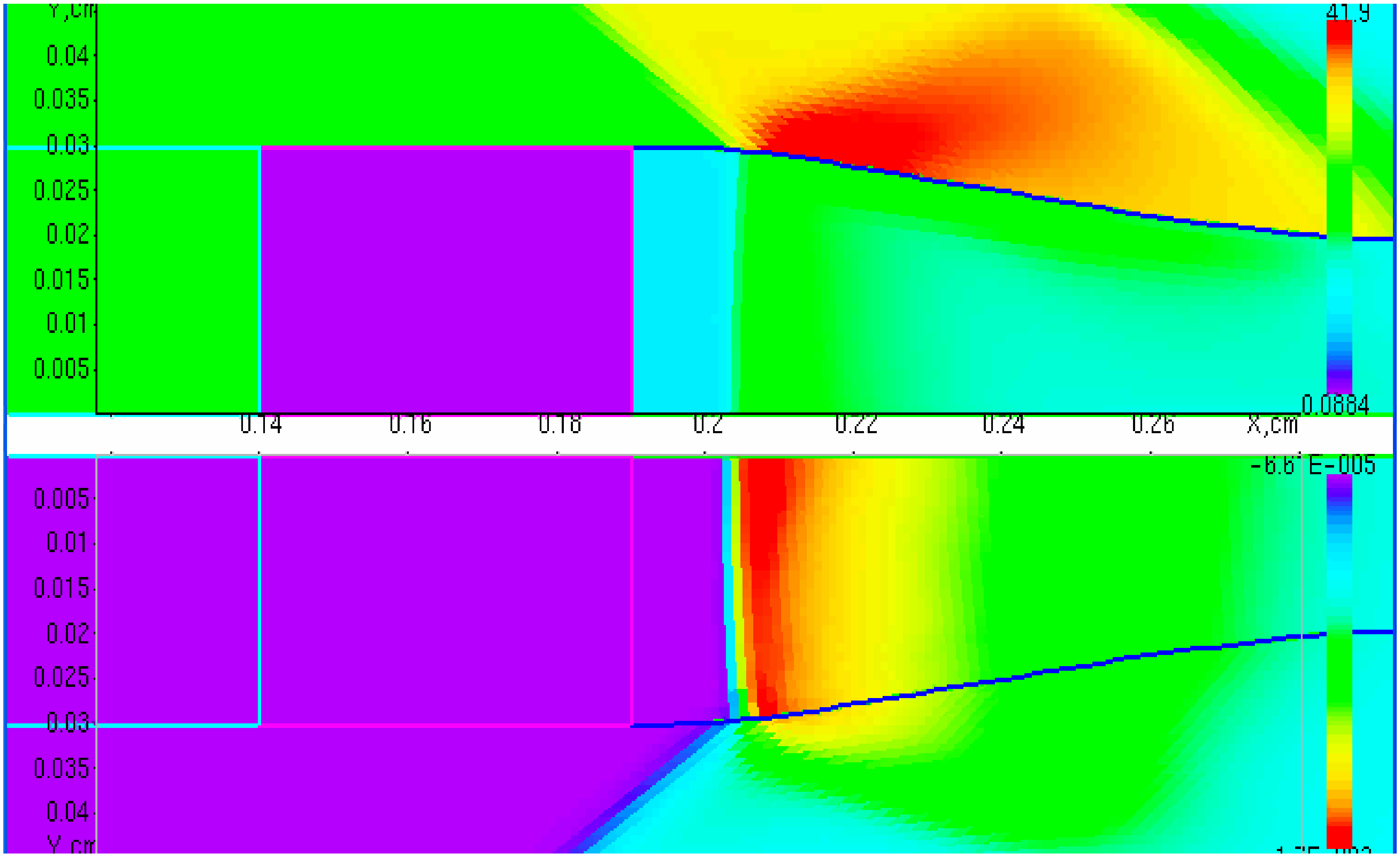
Hydrogen compression in SMC (time 0 ns)



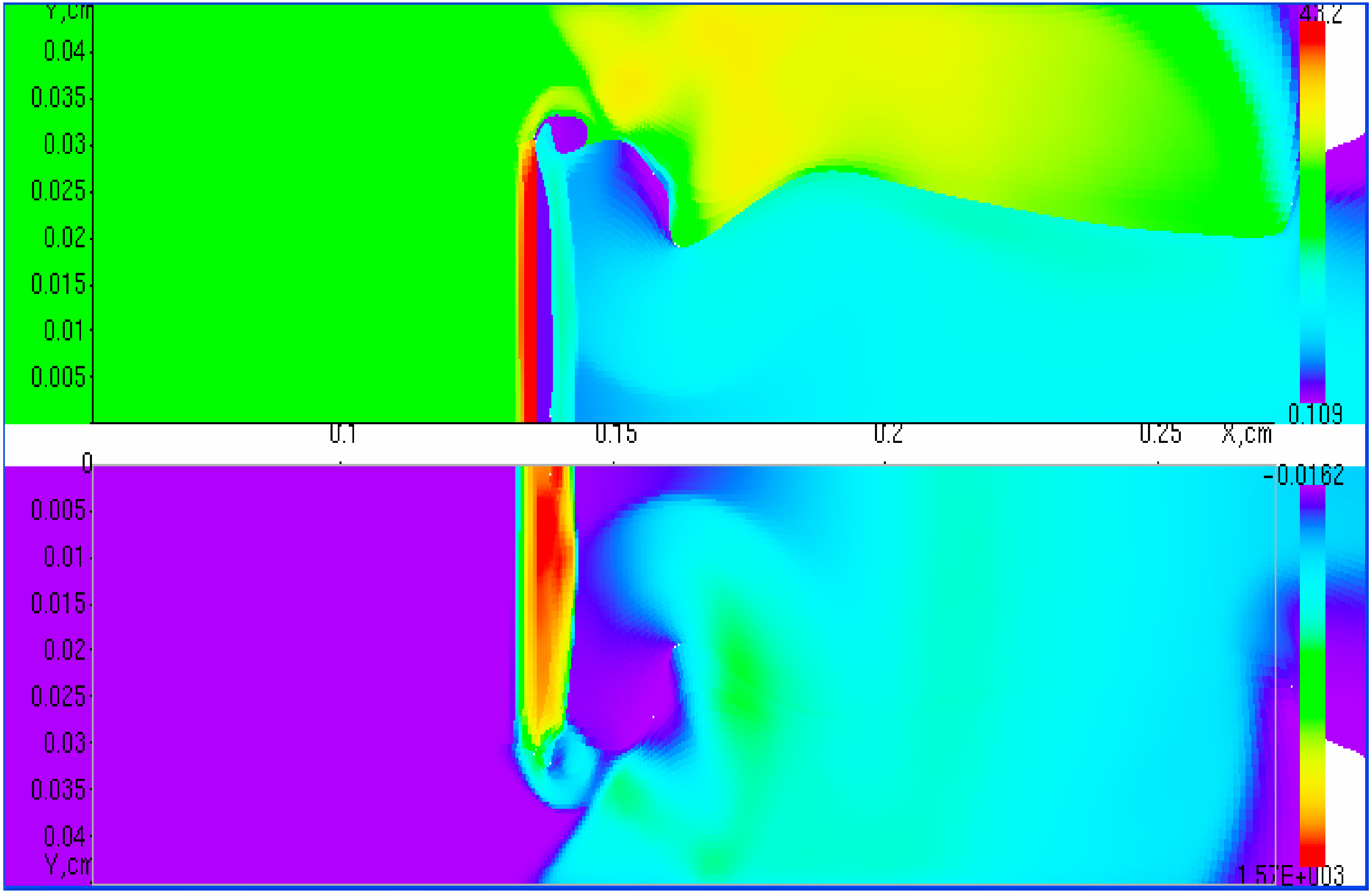
Hydrogen compression in SMC (time 90 ns)



Hydrogen compression in SMC



Hydrogen compression in SMC (130 ns)

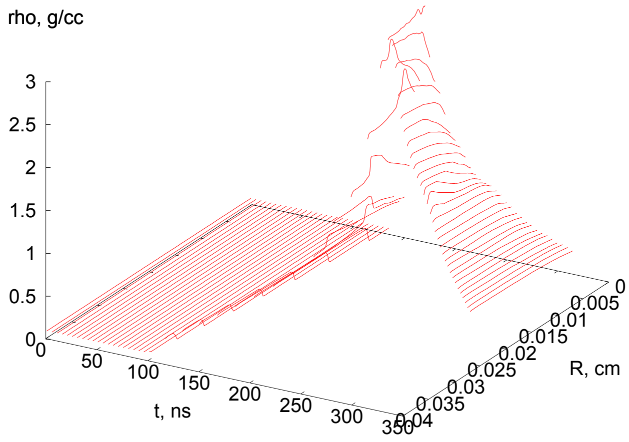


Laplas

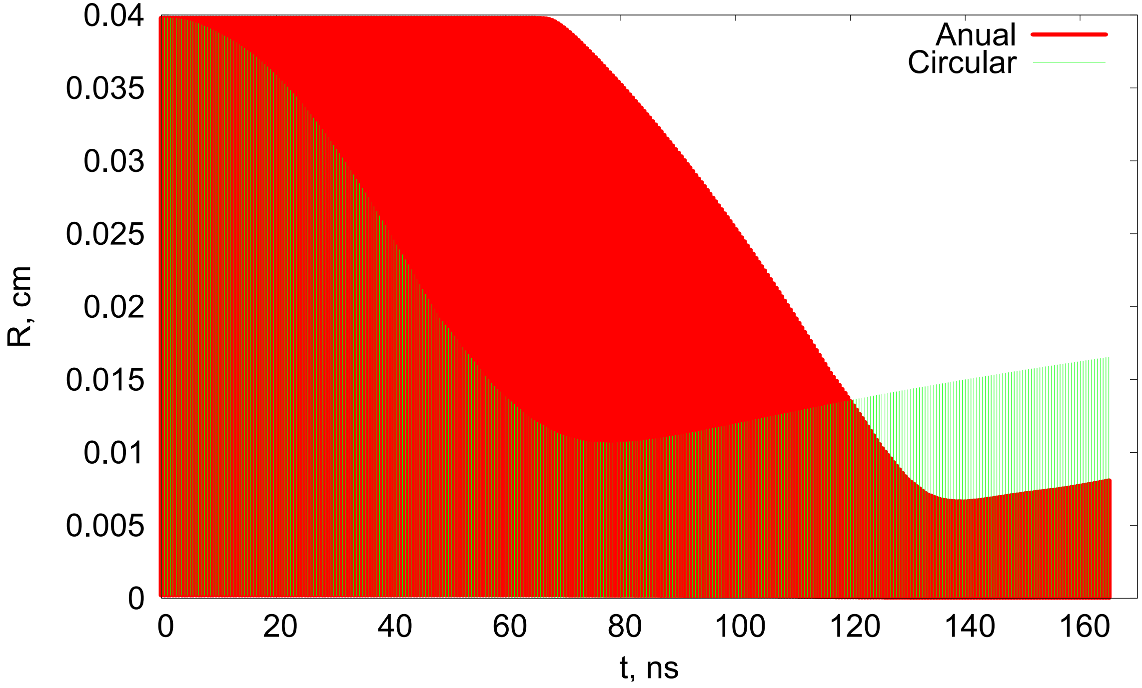
2 GeV/u U
$1 \cdot 10^{12}$ ions
50 ns pulse

Annular beam: Rout=1.6mm Rin=0.6mm
Circular beam: FWHM=1.5mm

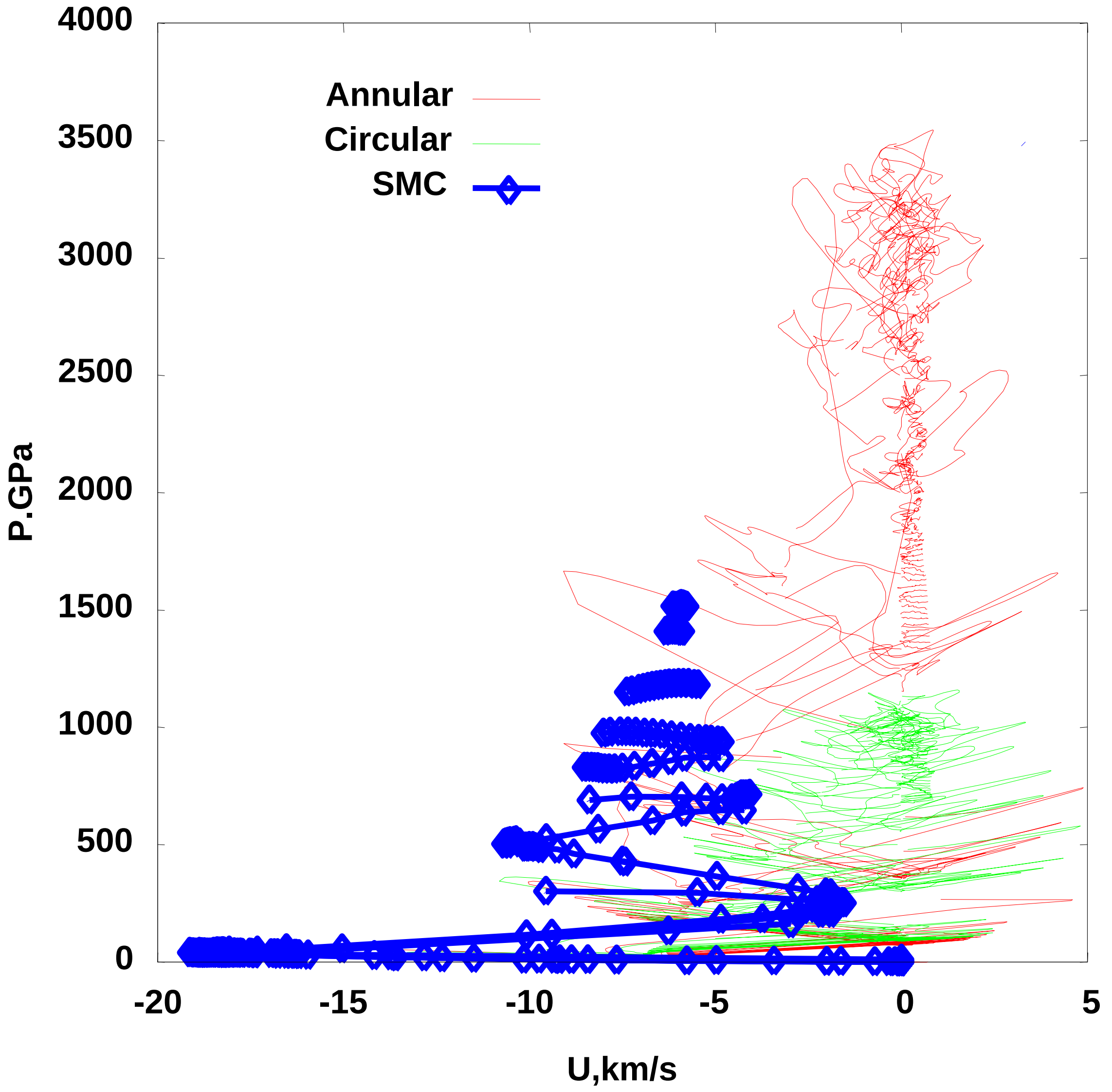
Density



Radius

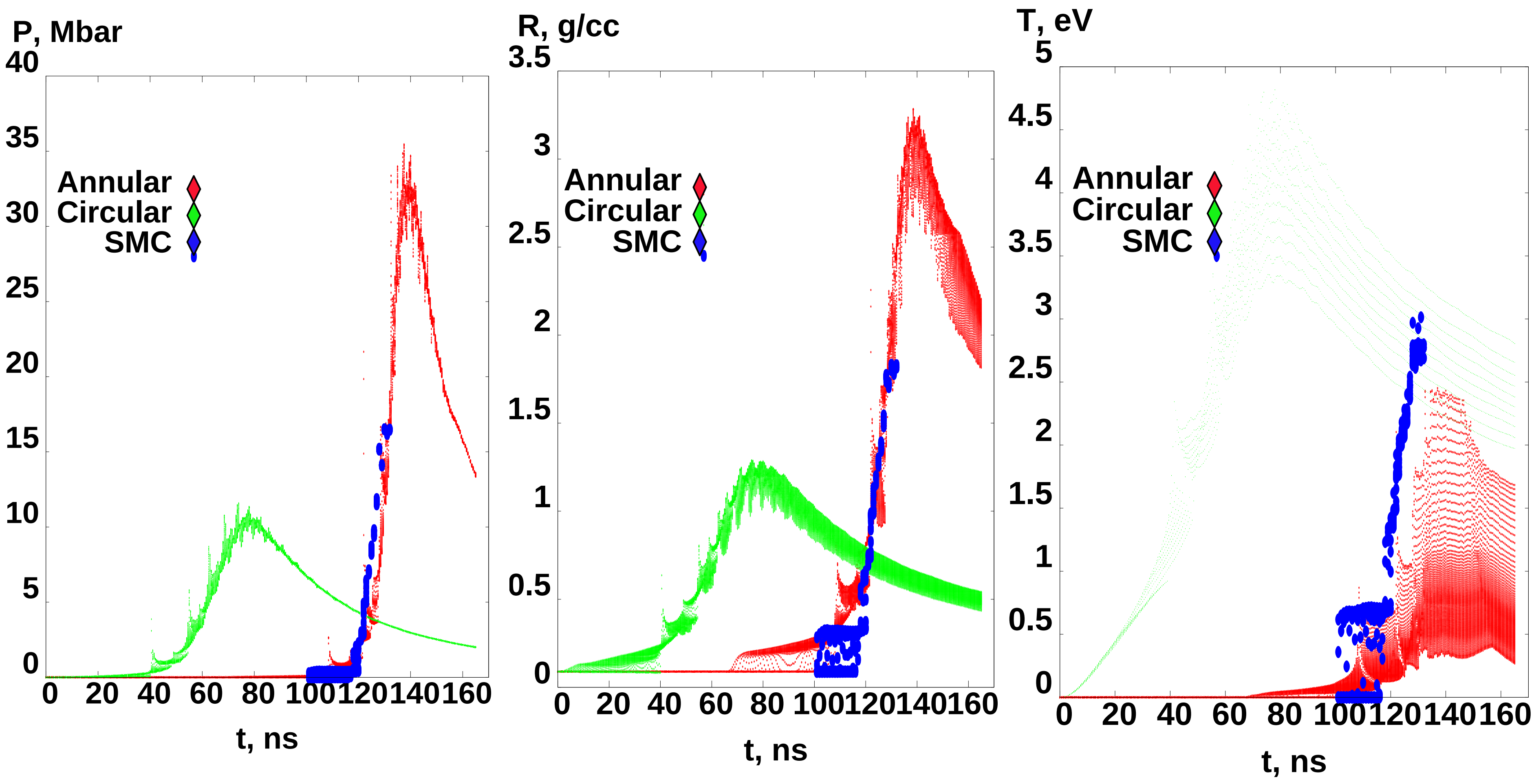


P-U diagram



Annular
Circular
SMC
4000
3500
3000
2500
2000
1500
1000
500
0
P,GPa
-20
-15
-10
-5
0
5
U,km/s

Laplas and SMC targets



Summary

SMC advantages:

+The scheme uses high efficiency of 2D cumulation effect and transmit the cumulative energy for 1D plain experimental set up.

+The scheme exploits high energy deposition in Bragg peak location and hydrodynamic energy focusing.

+The region under investigation is not exposed by the HIB.

+The control parameters of SMC is geometry and it may be easily fixed with high precession.

Conclusion:

The best scheme for experimental research of extremely high compressed matter is SMC

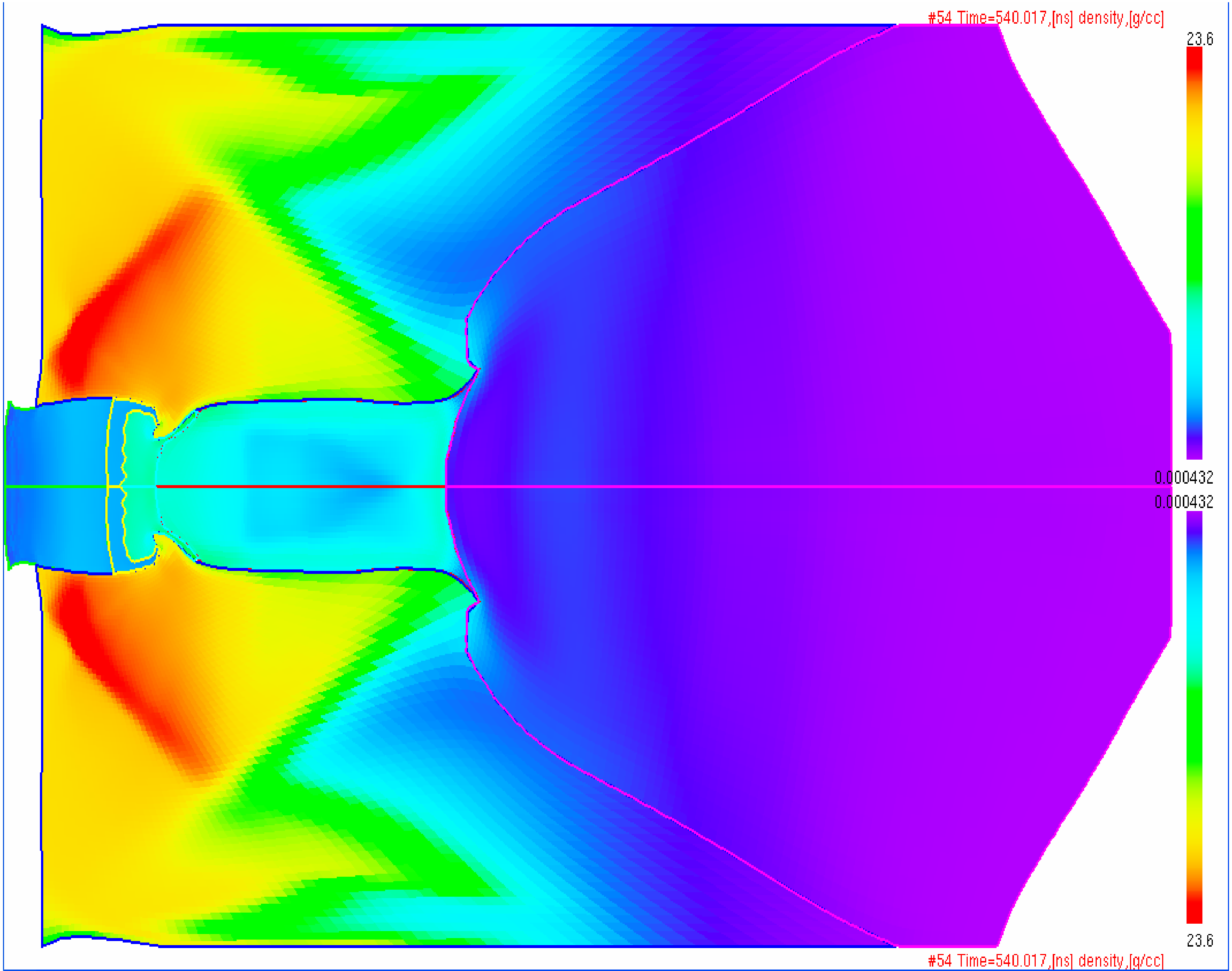
Thank you for attention

Dependence of parameters on angle of cone

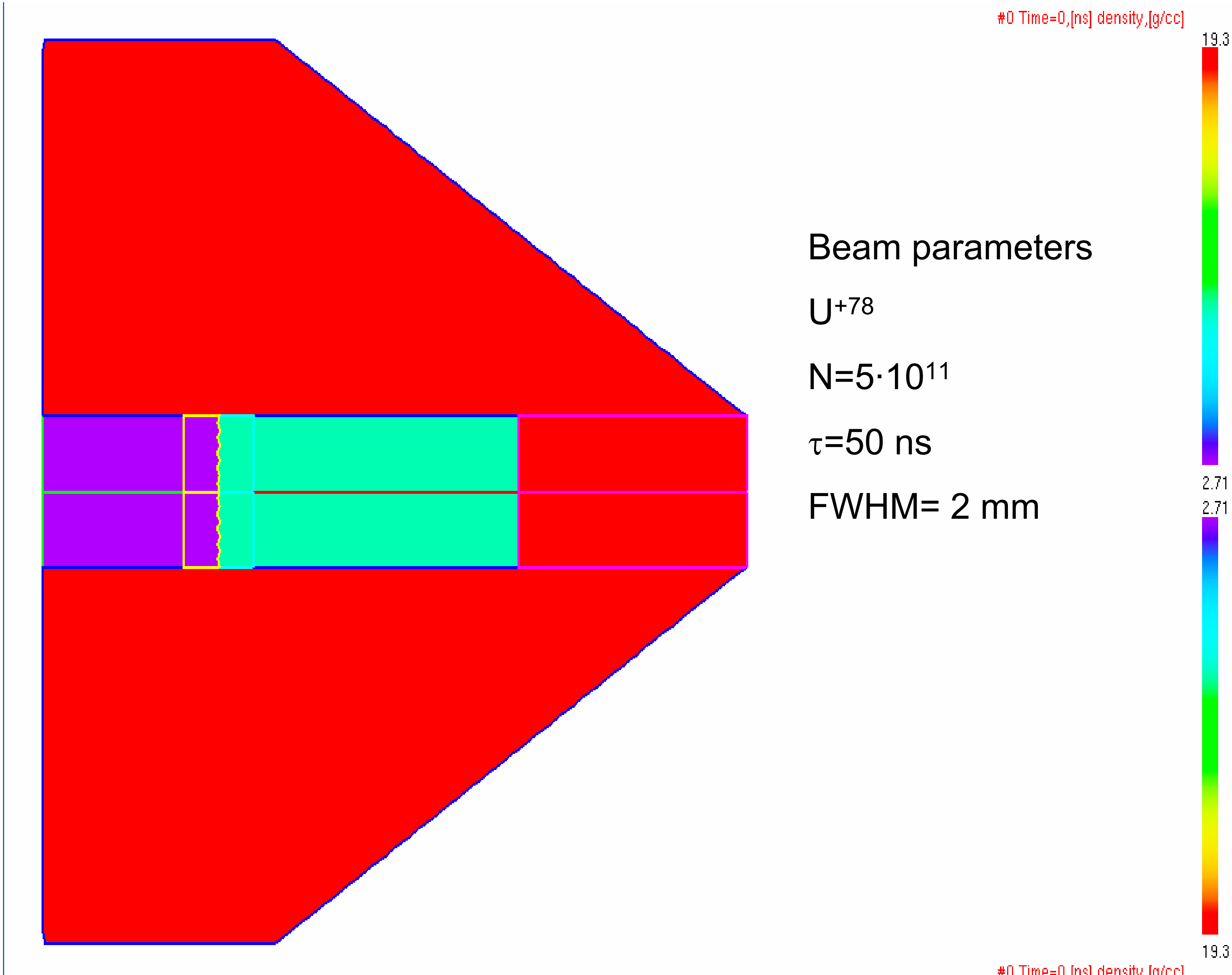
α,°	P, Mbar	U, km/s	T, кК	ρ,g/cm^3	*h, mm*
40	11 / 26	8 / 12	11 / 26	18.7 / 22.8	>0.2
32	15 / 35	10 / 16	15 / 35	19.7 / 22.5	0.2
19	36 / 57	14 / 19	36 / 57	23.5 / 27	0.05

Beam parameters
U^{+78}
$N=1\cdot10^{12}$
τ=50 ns
FWHM= 1.5 mm / 1mm

RM instability



RM instability



Beam parameters

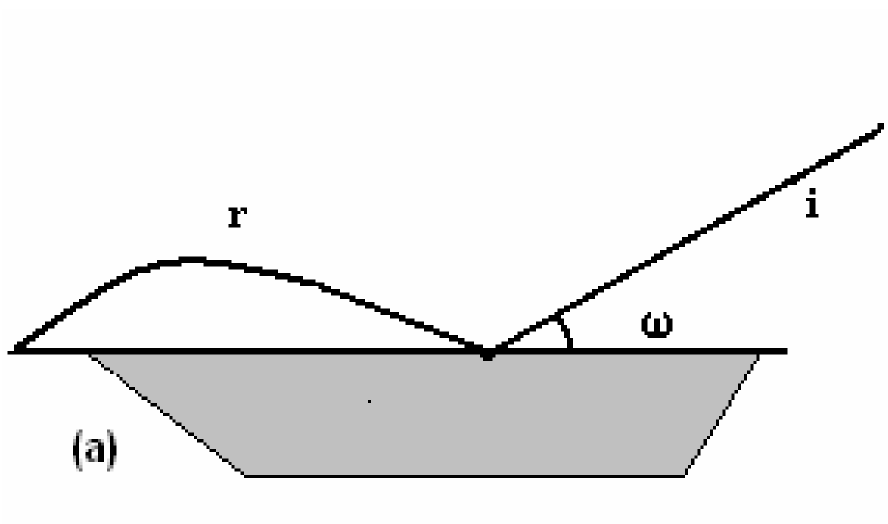
U^{+78}

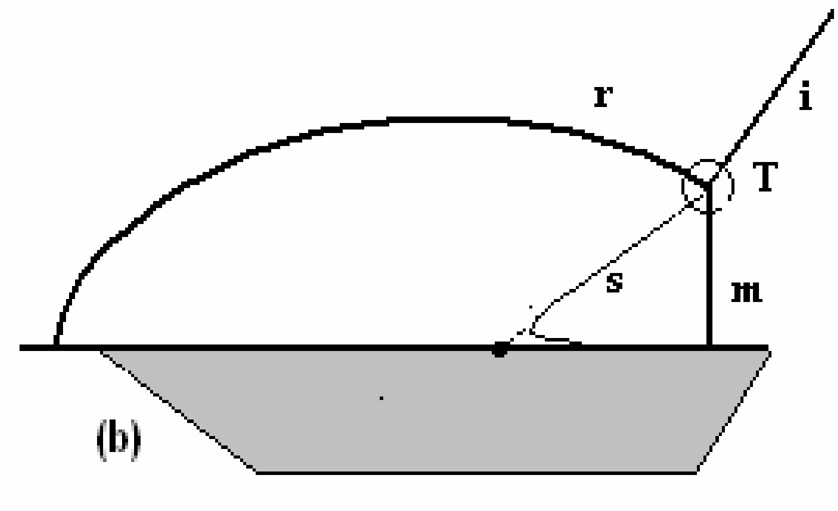
$N=5\cdot10^{11}$

τ=50 ns

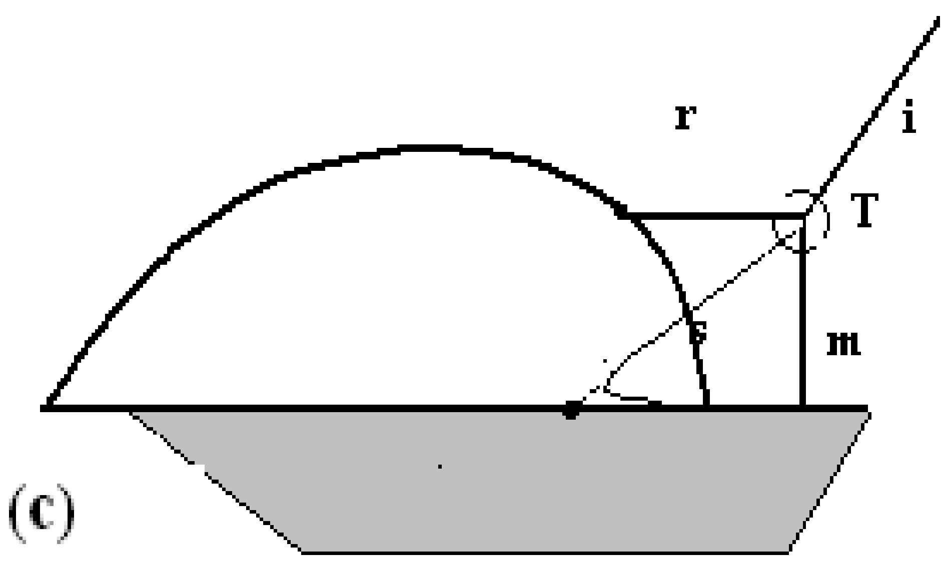
FWHM= 2 mm

Regular and irregular (Mach) shock wave reflections



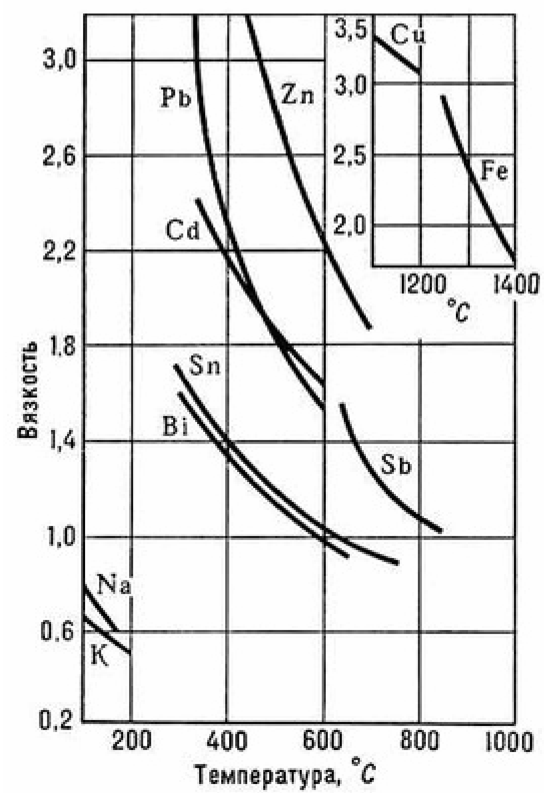


Simple Mach reflection



Double Mach reflection

Viscosity of metals in cPs



Estimation of SW thickness

Viscosity

$$x_\eta \sim \eta \frac{U}{P} = 3[\mathrm{cPs}]\frac{15\cdot 10^{3}[\mathrm{m/s}]}{15\cdot 10^{11}[\mathrm{Pa}]} = 3\cdot 10^{-8}\,\mathrm{m}$$

Thermal conductivity

$$x_T \sim \frac{\lambda}{c_v \rho D} = \frac{170[\mathrm{W/m/K}]}{140[\mathrm{J/kg/K}]\cdot 19.25\cdot 10^{3}[\mathrm{kg/m^3}]\cdot 15\cdot 10^{3}[\mathrm{m/s}]} = 4.2\cdot 10^{-9}\,\mathrm{m}$$

Estimation of boundary thickness

Viscosity

$$x_\eta \sim \eta \frac{U}{P} = 3[\text{cPs}] \frac{15 \cdot 10^3 [\text{m/s}]}{15 \cdot 10^{11} [\text{Pa}]} = 3 \cdot 10^{-8}\,\text{m}$$

Thermal conductivity

$$x_T \sim \sqrt{\frac{\lambda \tau}{c_v \rho}} = \sqrt{\frac{170[\text{W/m/K}] \cdot 10^{-7} [s]}{140[\text{J/kg/K}] \cdot 19.25 \cdot 10^3 [\text{kg/m}^3]}} = 2.5^{-6}\,\text{m}$$