Detonation parameters ultrafine of low-density PETN and RDX-based high explosive

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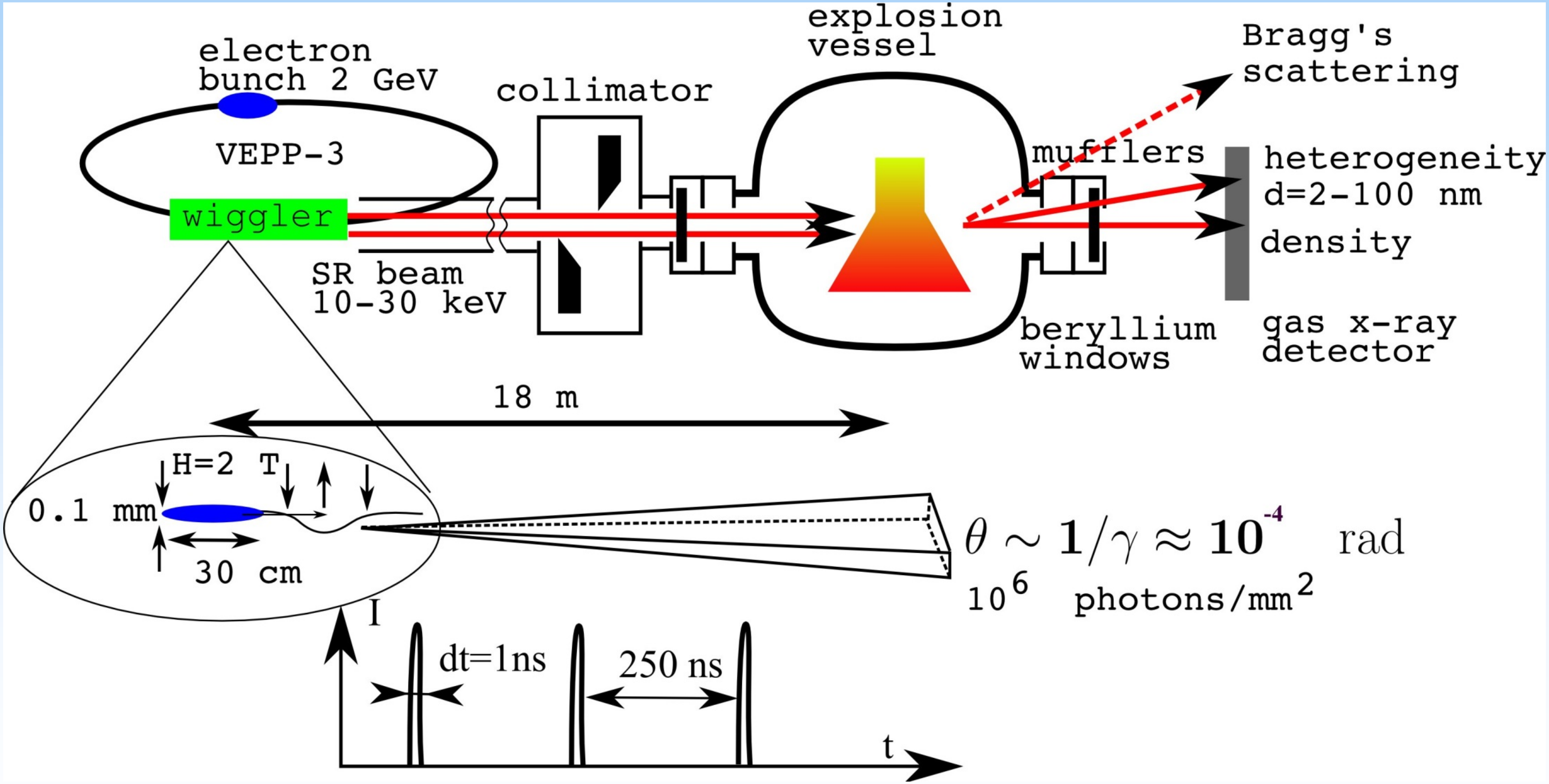
Objective

Synchrotron radiation (SR) has a number of unique features. Major ones are high flow intensity, which allows using very short exposure time ($\tau \leq 1$ ns), high frequency ($\Delta t = 5 \div 250$ ns) and small angular divergence. Due to these advantages as compared with a conventional X-ray pulse apparatus, it is possible to register radiation passing through a matter, producing a well-resolved multiframe pattern of density distribution in shock waves and the detonating high explosive.

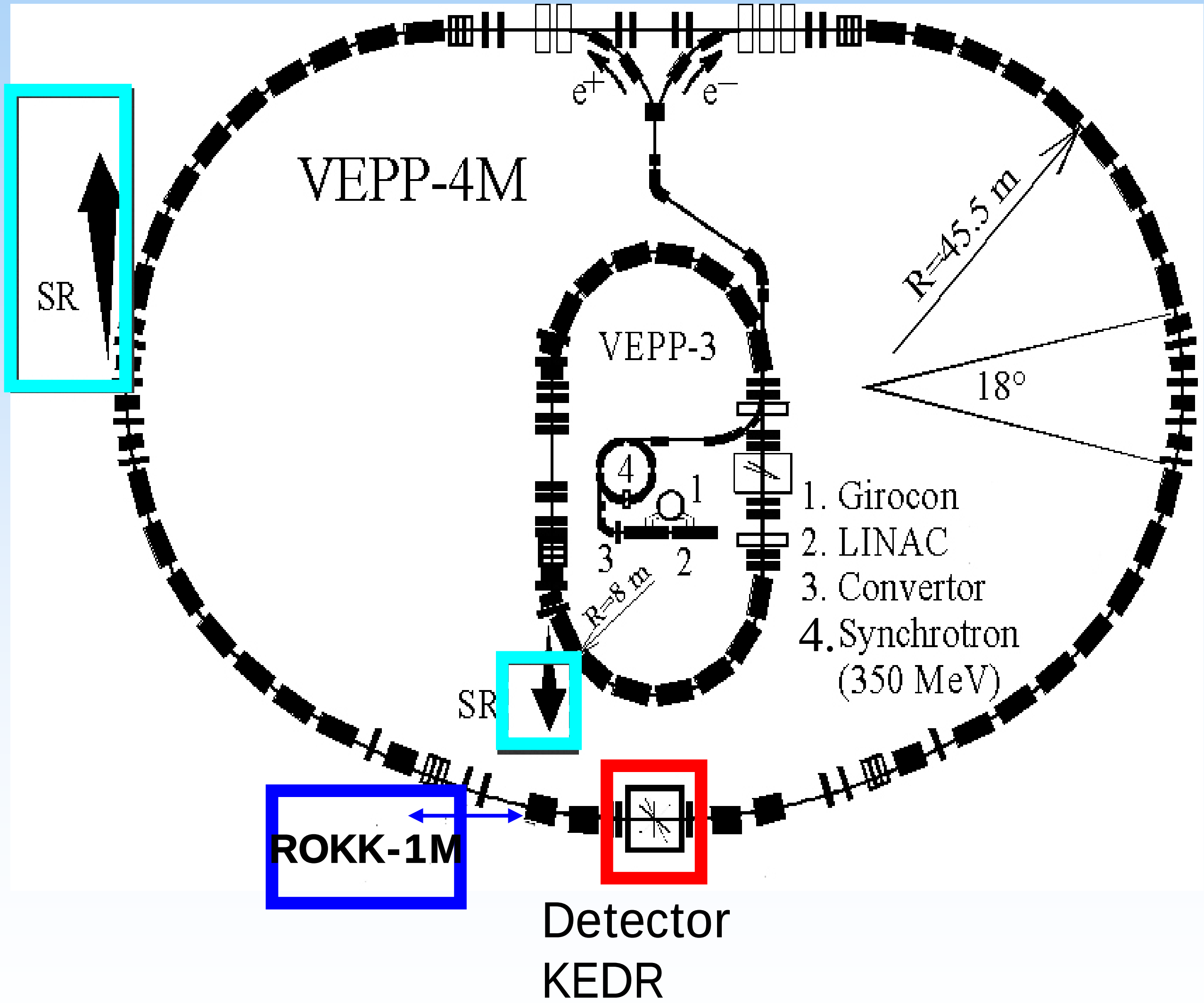
Samples of HE charges

The bulk ultrafine PETN+soda and RDX+soda mixtures(35/65). This mixed HE has a very low initial density (~ 0.5 g/cm^3) and low detonation velocity (~ 2 km/s). With a small critical diameter (~ 2 mm), this composition is very promising if applied to explosion welding [1].

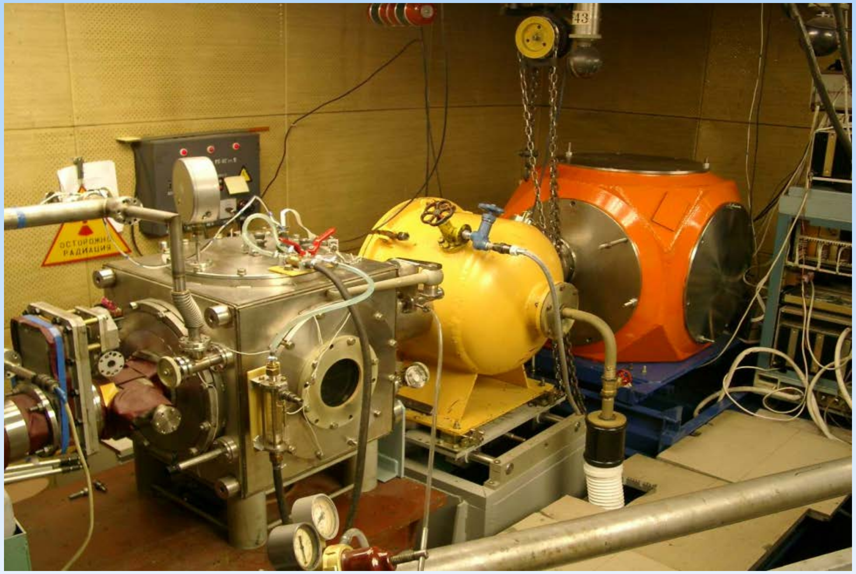
Experimental setup. General scheme

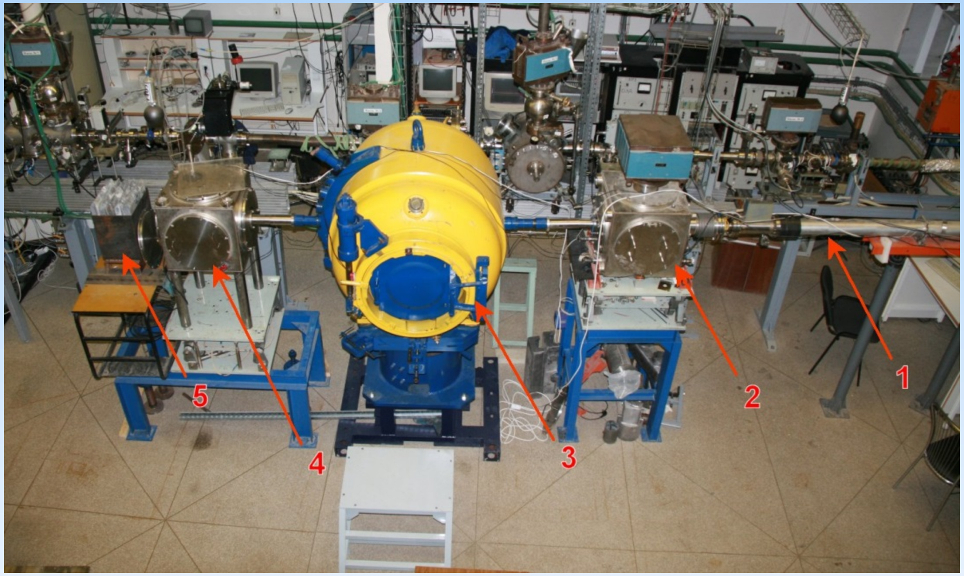


Acceleration complex VEPP-3 - VEPP-4 is the basis of the detonation experiments



Experimental base in INP

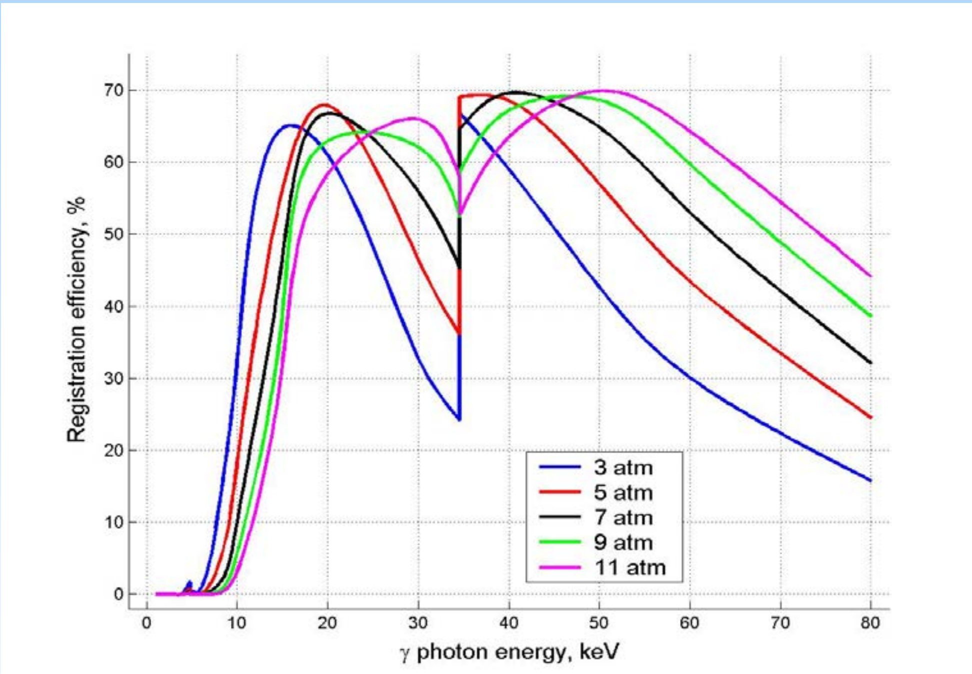


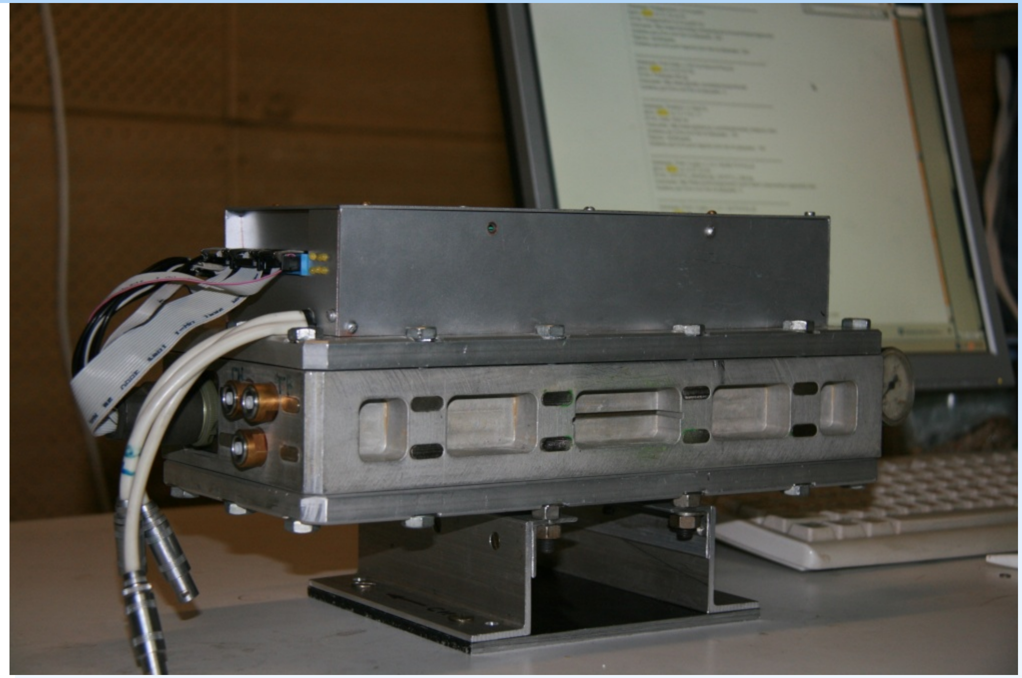


Stand for study of detonation processes on VEPP-3 beam line 0

General view of the new station in the VEPP-4 bunker. 1 - inlet pipe for SR, 2 - unit of collimators, 3 - explosion chamber, 4 - recording unit, 5 - lead trap

DIMEX - detector for study of the detonation processes.

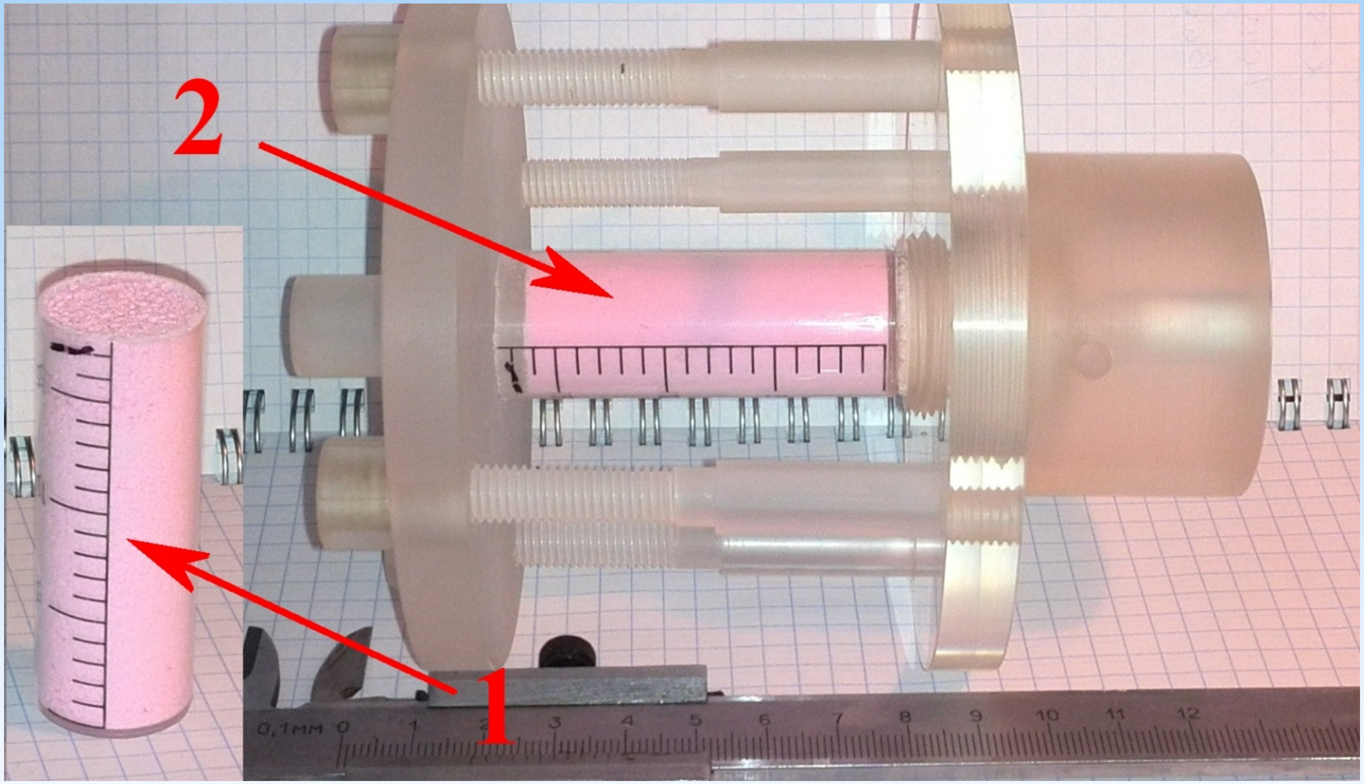




Dependence efficiency of registration from photon energy.

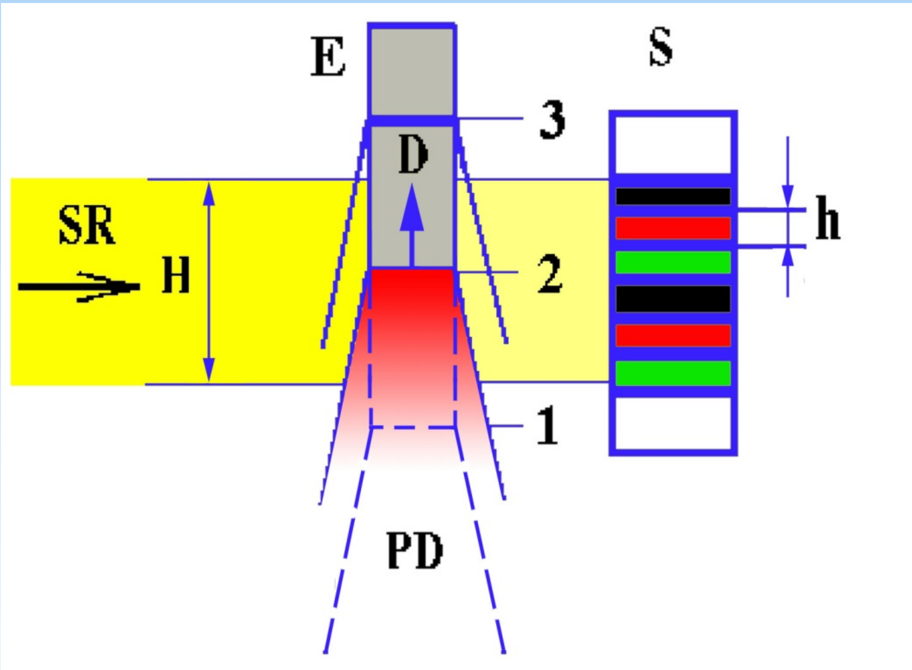
General view of DIMEX. Channels size 100 мкм, Channel numbers – 512, number of frames – 32, time between frames – 125 нс.

Experimental assemblies



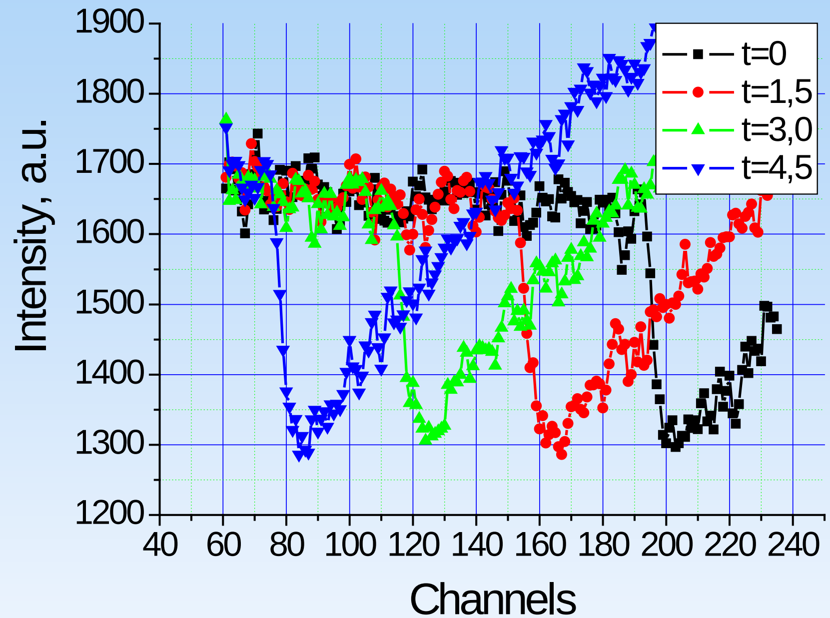
General view of an experimental assembly.
1 - RDX, 2 - PETN

Experimental setup.



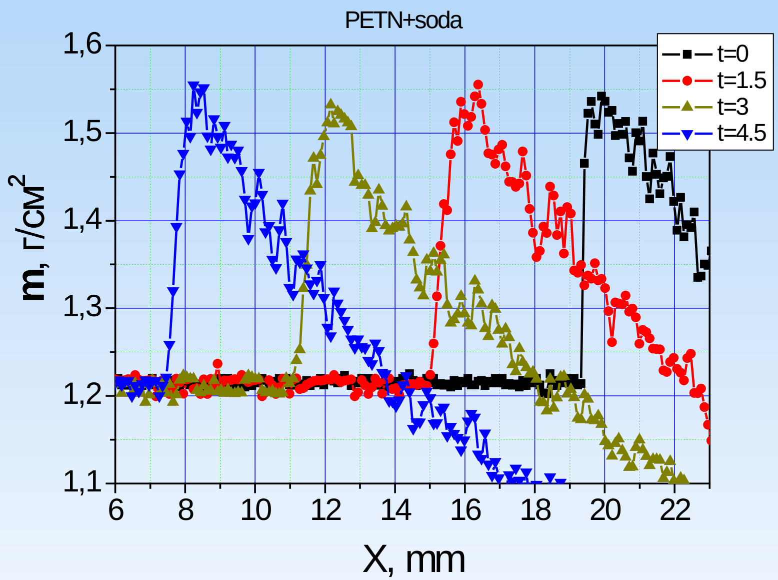
Experimental setup.

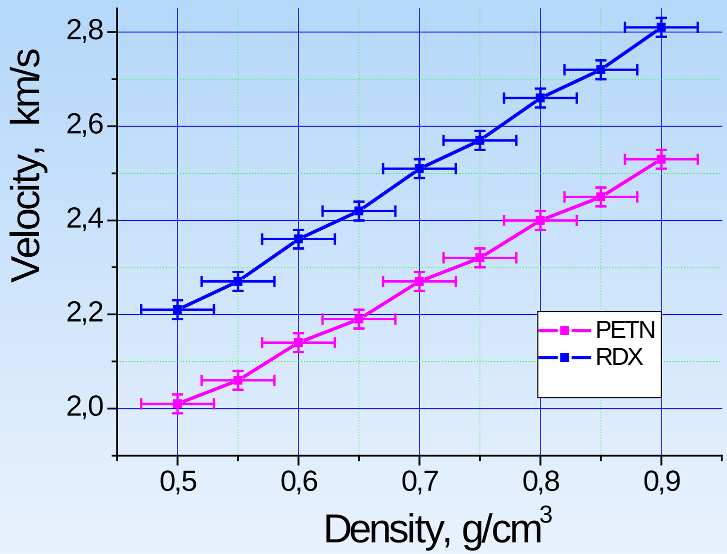
E is the explosive charge; SR is the SR beam plane; H is the beam width; S is the detector DIMEX; h is the registration channel width; D is the detonation front position at moments 1, 2, and 3; PD denotes the scattering products of detonation.



Relative intensity variation along the charge axis at detonation of RDX. Detector channels 0,1 mm wide are plotted along the X axis. The time between frames – 1,5 μs.

Detonation velocity

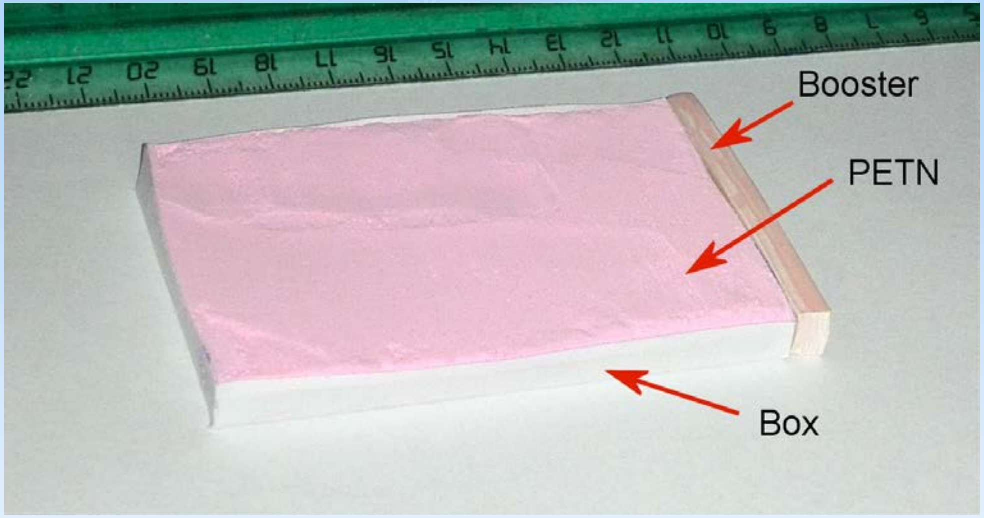


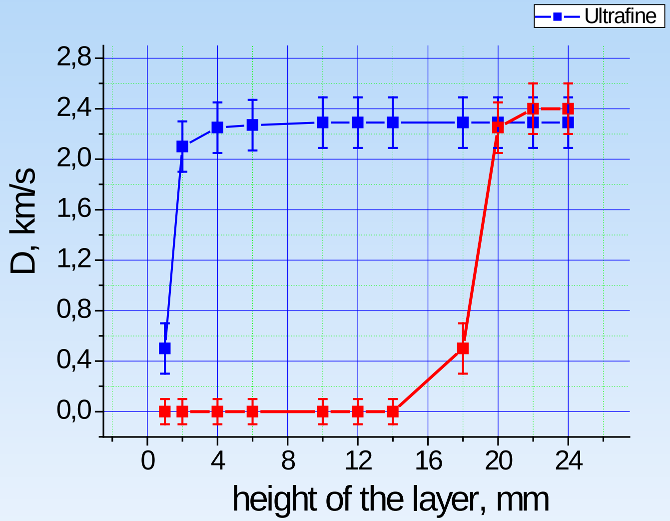


The mass distribution vs. time. Profiles are given with interval of 1.5 μs. RDX + soda mixture; velocity of 2.35 km/s.

Detonation velocity vs initial density of PETN+soda and RDX+soda mixtures

Experimental setup.

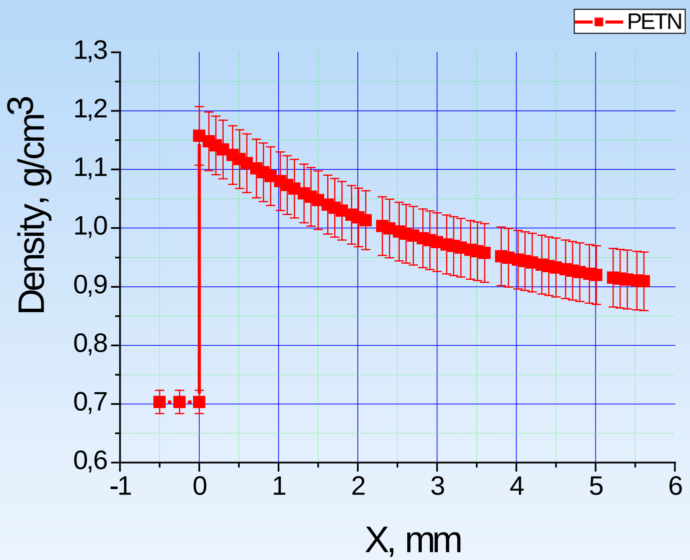


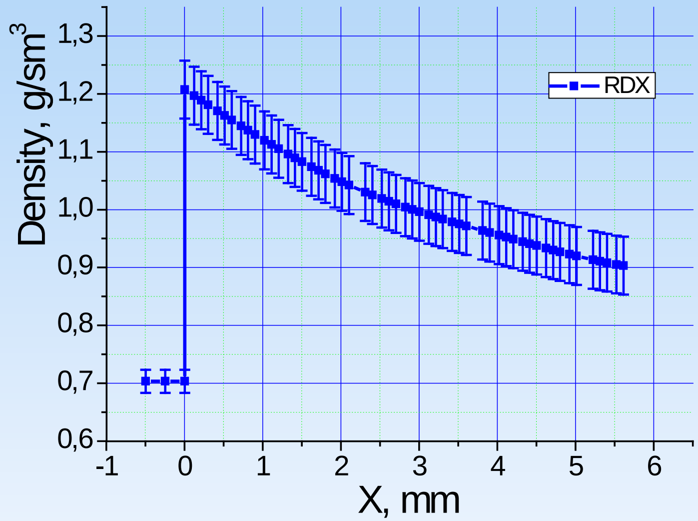


General view of box with PETN + soda mixture. HE layer height H = 3 mm.

Detonation velocity vs initial height of PETN + soda mixture layer.

Density profile.

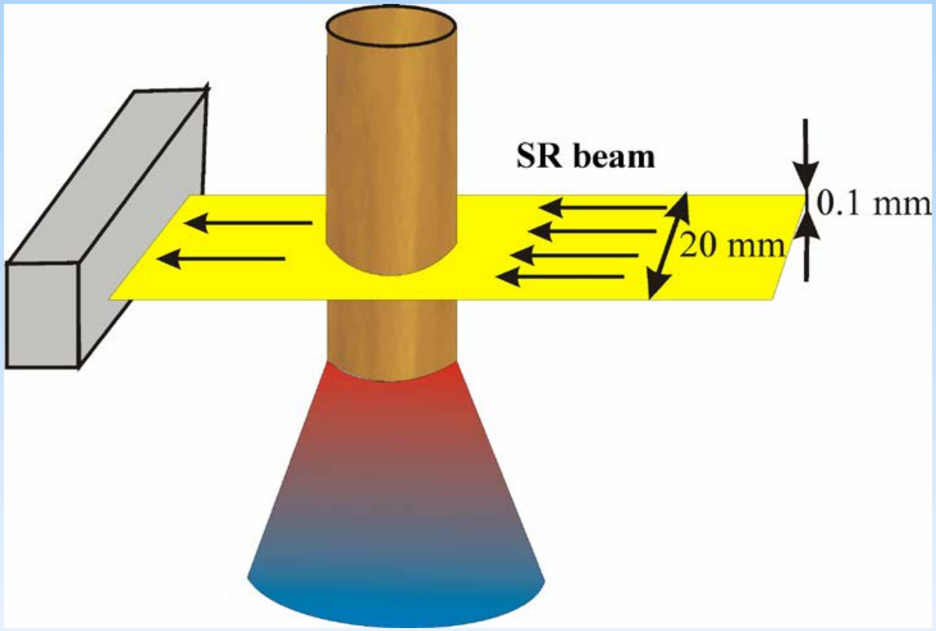


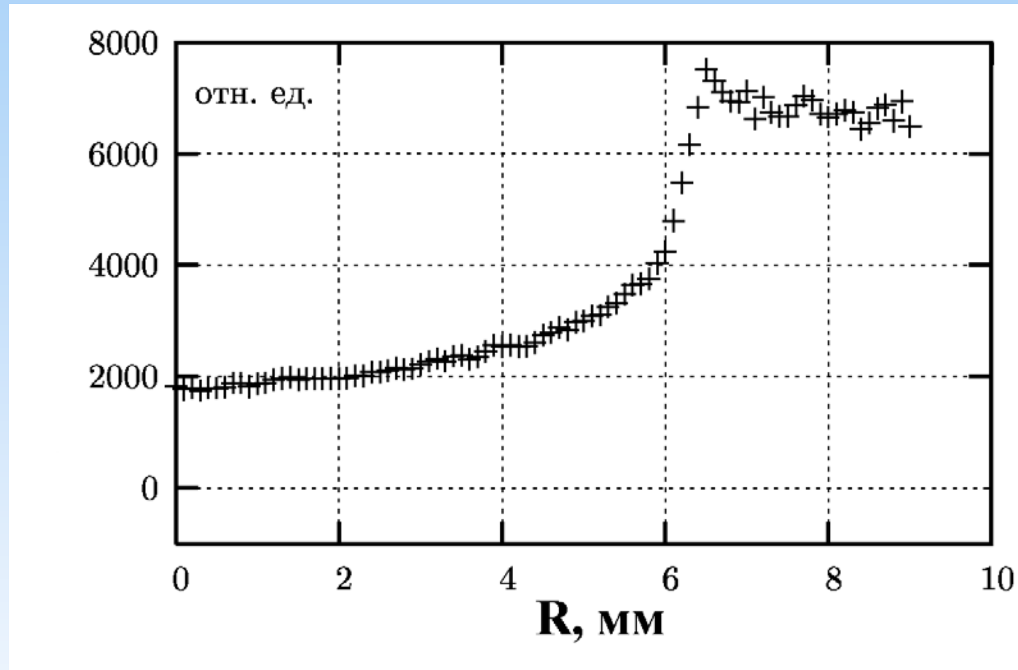


Density profile in PETN+soda detonation front.

Density profile in RDX+ soda detonation front.

Measurement 3D density distribution.

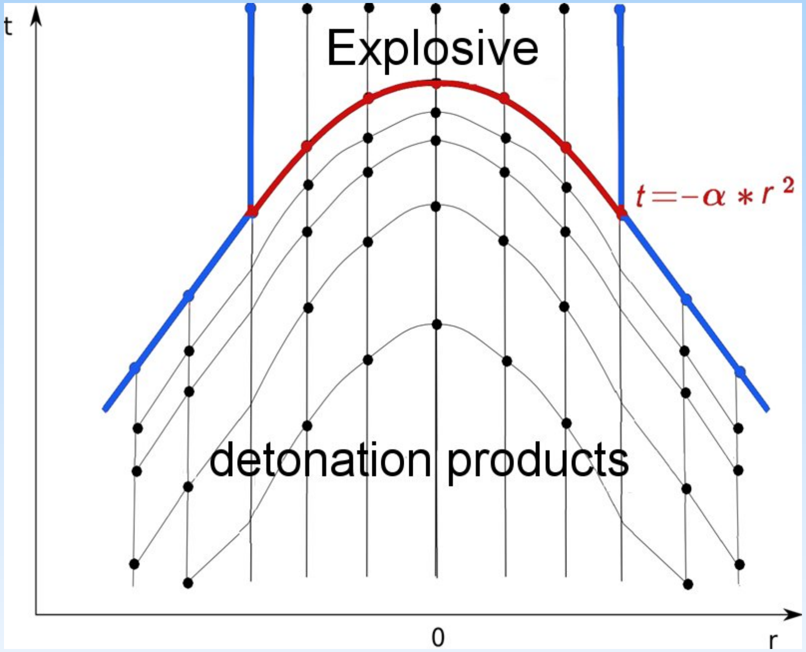




Set-up of experiments on measurement of absorption in spread of explosion products. .

Transmitted radiation intensity variation along the radius for one frame at detonation of PETN.

Reconstruction 3D density distribution.



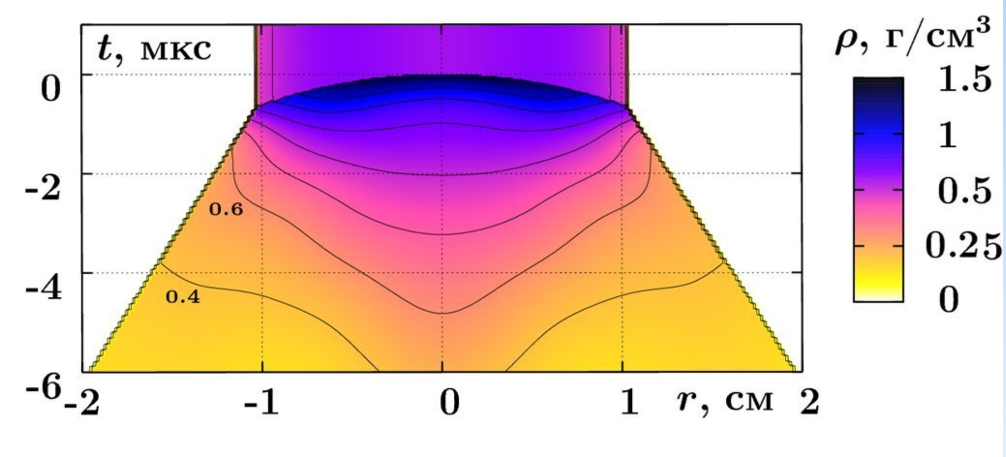
$$G(\vec{p}) = \sum_{i,j} (F(x_j, t_i) - F'_{\vec{p}}(x_j, t_i))^2$$

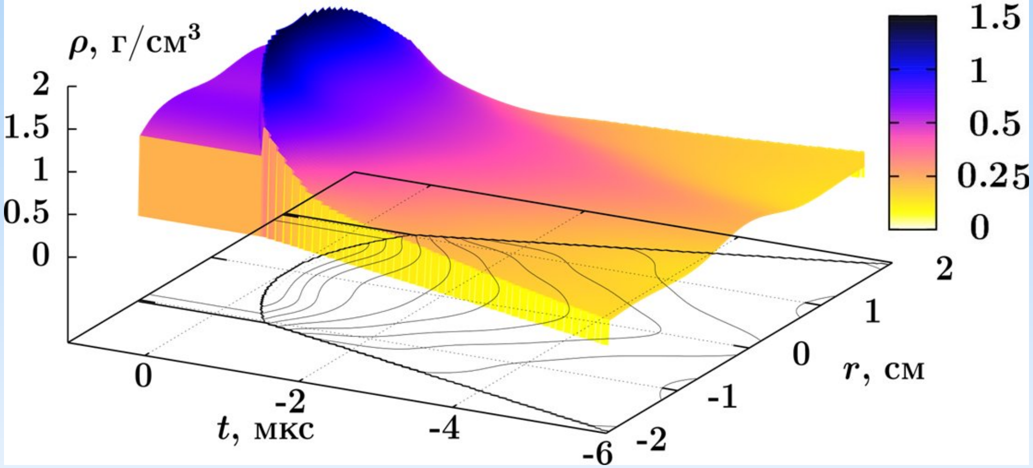
$$F'_{\vec{p}}(x_j, t_i) = \int_{-\sqrt{R_0^2 - x_j^2}}^{\sqrt{R_0^2 - x_j^2}} \rho_{\vec{p}}(t_i, \sqrt{x_j^2 + y^2}) dy$$

Scheme of approximation mesh generation for density reconstruction. Thick lines: density discontinuities; thin lines: curves along which interpolation splines are created; dots: areas where varying density value is given.

Approximation of density vs time with fixed radius. Top: radius is inside charge; bottom: detonation products.

3D density distribution.





Reconstructed density distribution in PETN+soda.

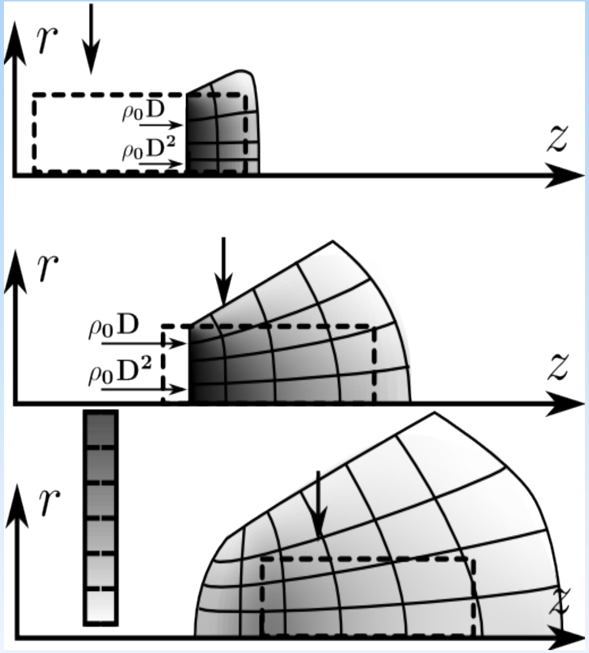
Reconstructed volume density distribution in PETN.

Reconstruction 3D distribution for density, pressure and velocity.

$$\frac{\partial r\rho u}{\partial r}+\frac{\partial r\rho v}{\partial z}=\frac{\partial r\rho}{\partial t},$$

$$\frac{\partial r\rho u^2}{\partial r}+\frac{\partial r\rho uv}{\partial z}+r\frac{\partial p}{\partial r}=\frac{\partial r\rho u}{\partial t},$$

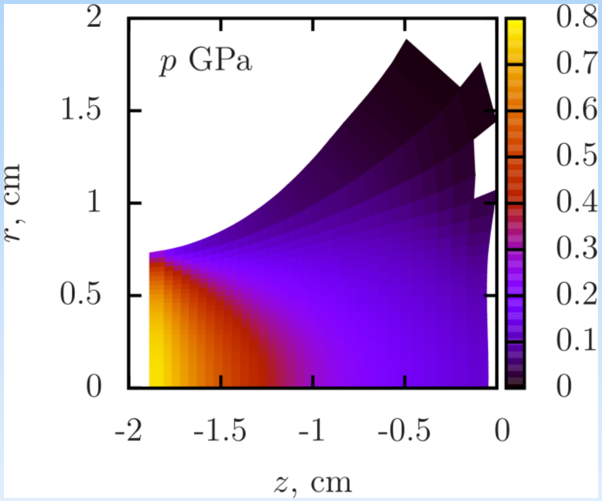
$$\frac{\partial r\rho v^2}{\partial z}+\frac{\partial r\rho uv}{\partial r}+r\frac{\partial p}{\partial z}=\frac{\partial r\rho v}{\partial t},$$

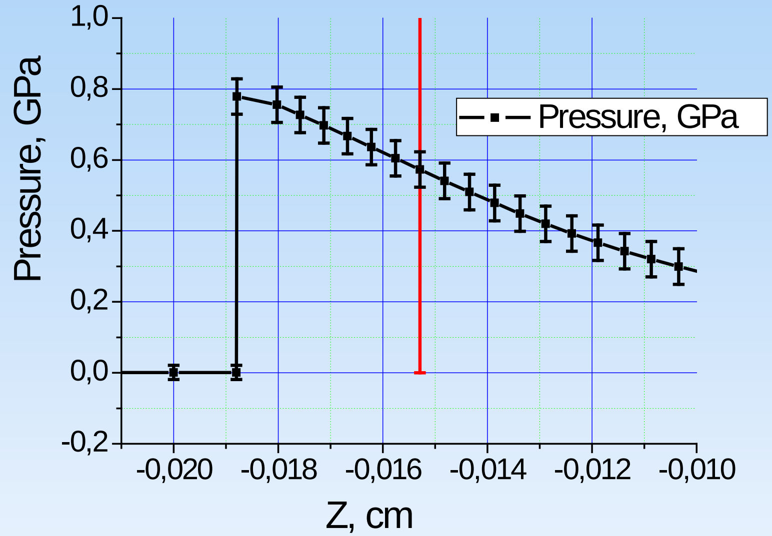


•Equations of continuity and motion; **ρ** is the density; **p** is the pressure; **u** and **v** are the axial and radial components of the velocity vector **v**; **r** and **z** are the radial and axial spatial coordinates; **t** is the time.

Scheme of set-up of gas-dynamical problem for calculation of detonation flow. Dotted line: initial borders of charge. Arrow: location of section to study.

Volume distribution of pressure

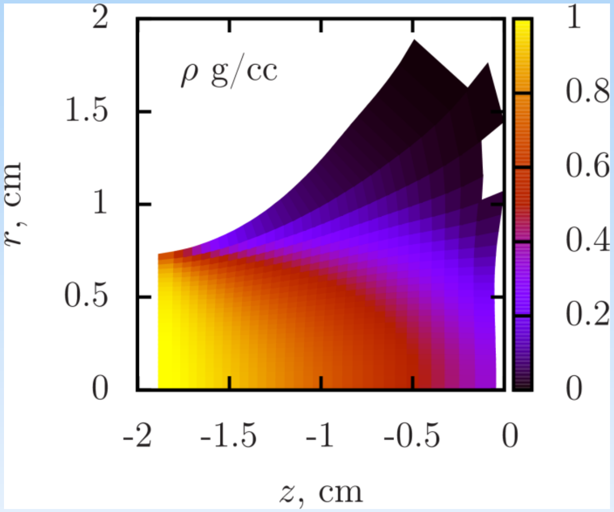


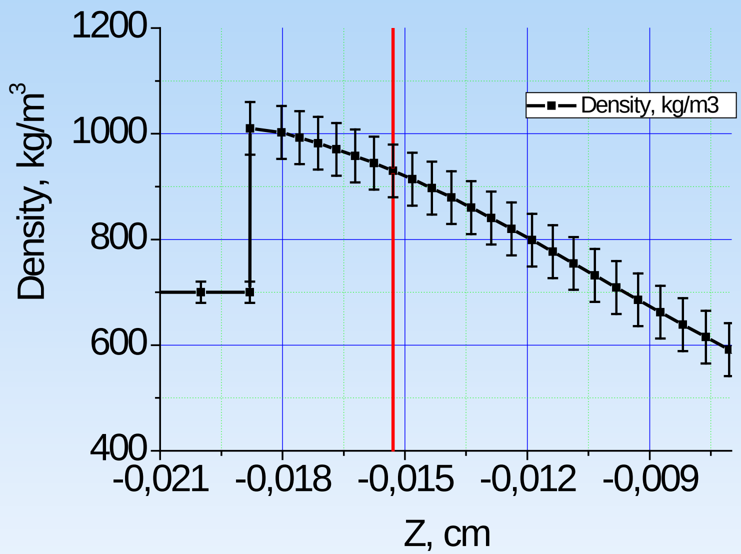


Volume distribution of pressure; density of 0.75 g/cm3

Pressure distribution along charge axis.

Space density distribution

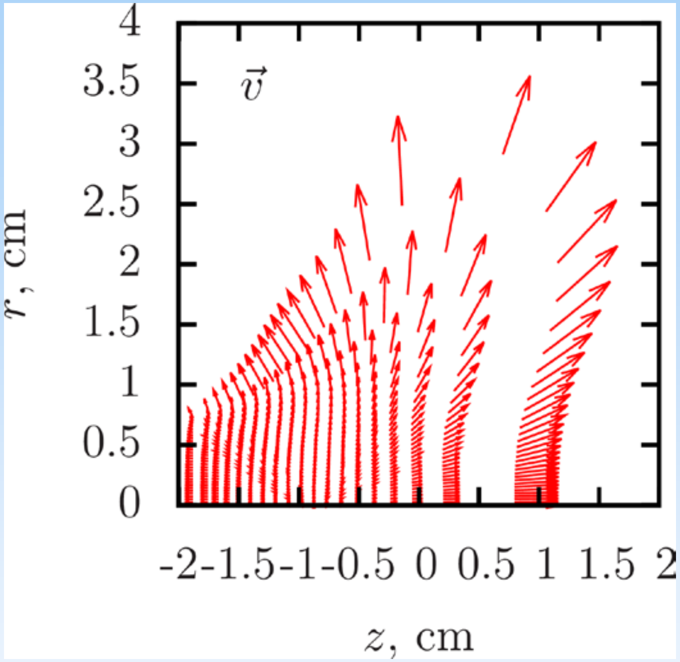


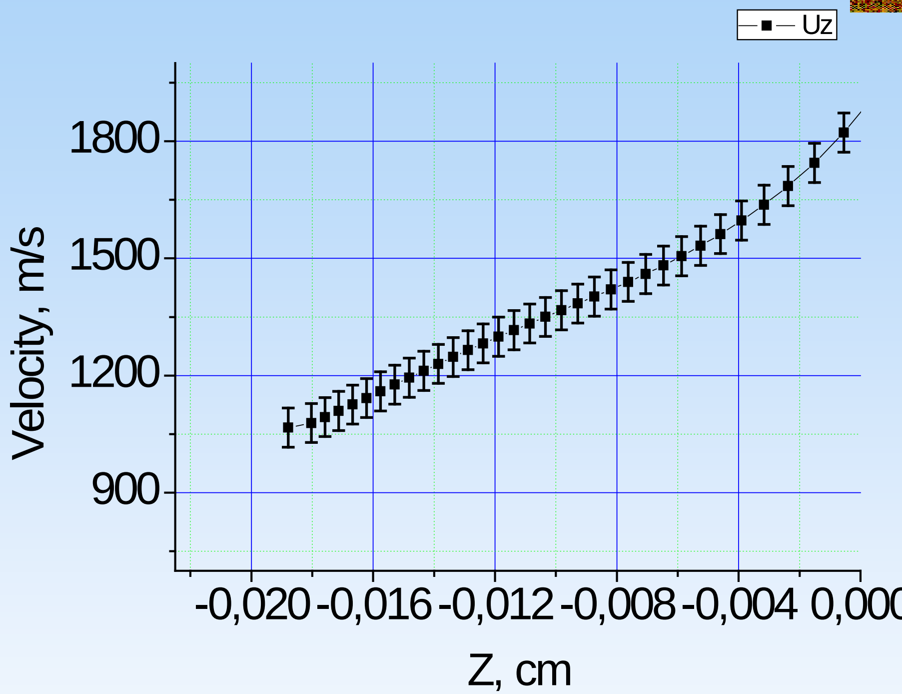


Space density distribution at detonation PETN.

Density distribution along charge axis.

Distribution of velocity

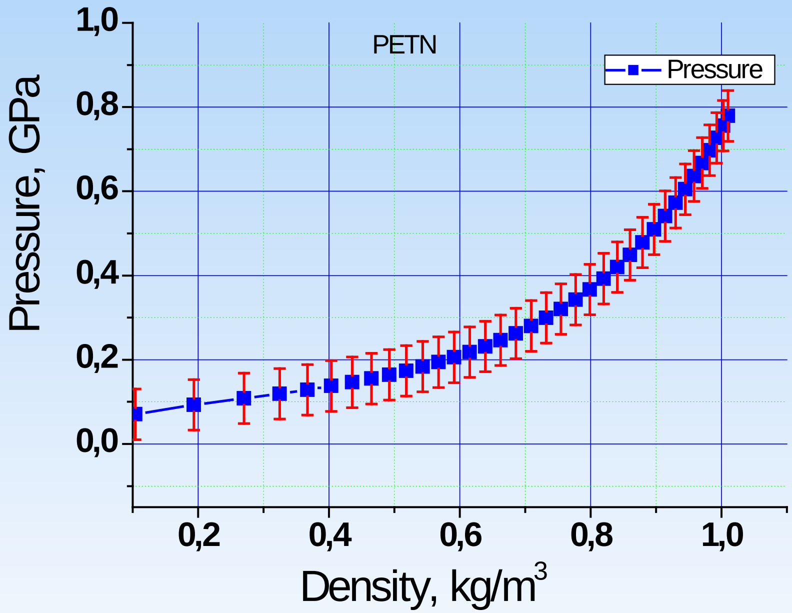


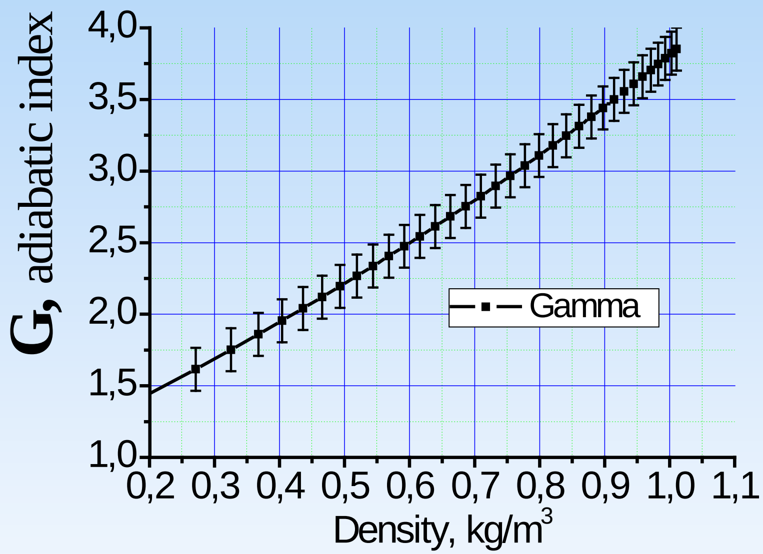


Distribution of velocity vectors of detonation products.

Distribution of velocity along charge axis

Adiabatic index



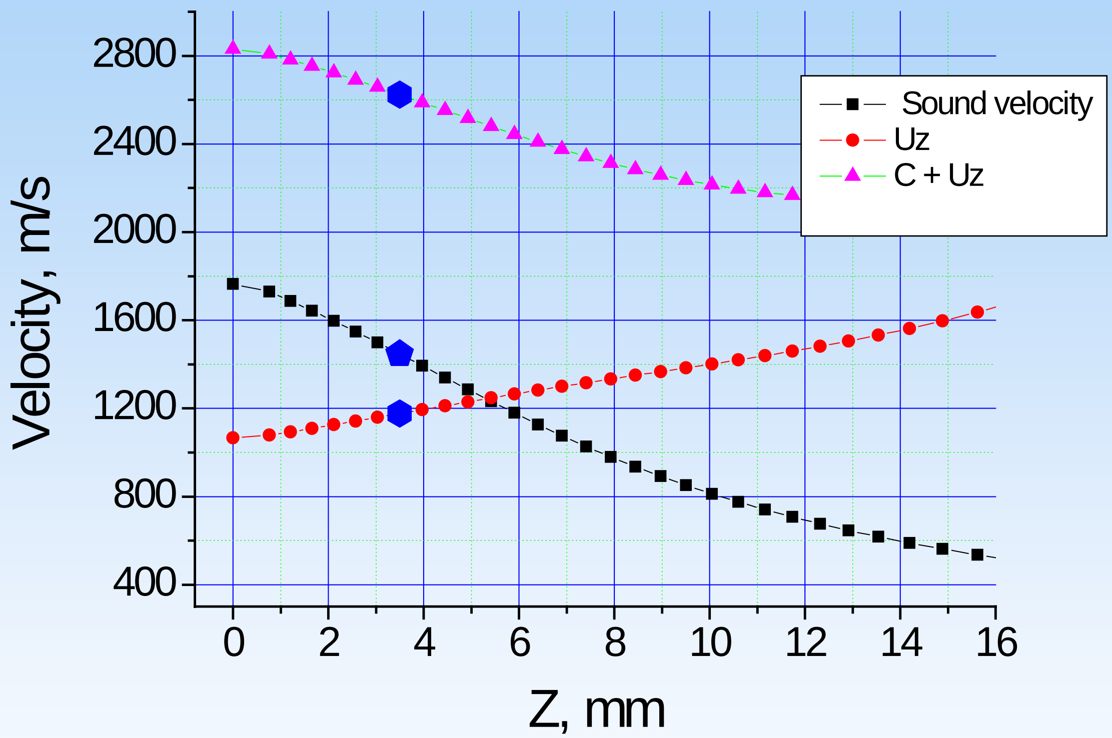


Reconstructed equation of unloading adiabat of detonation products.

$$p = p_*(\rho / \rho_*)^{G(\rho)}$$

Chart of adiabatic index of expanding products.

Speed of sound



Charts of expansion velocity **Uz**, speed of sound **C** and their sum along charge axis. Blue dot: Jouget plane

Main results

Techniques using SR on VEPP-3 were applied to the measurement of density distribution in a detonation front.

The measured density distribution and the width of the zone of chemical reaction of ultrafine PETN + soda and RDX + soda (35/75) mixtures. Max density - 1.2 g\cm^3, the width - 3.5 mm.

The equation of state was obtained for explosion products in the form of pressure versus density, *P(r)*.

Thank you

for your attention!