# HIGH SPEED CRYOGENIC MONODISPERSE TARGETS FOR HIGH INTENSITY CYCLIC AND LINEAR ACCELERATORS

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*Abstract*

The basic possibility of creation of high speed cryogenic monodisperse targets is shown. According to calculations at input of thin liquid cryogenic jets with a velocity of bigger 100 m/s in vacuum the jets don't manage to freeze at distance to 1 mm and can be broken into monodisperse drops. Drops due to evaporation are cooled and become granules. High speed cryogenic monodisperse targets have the following advantages: direct input in vacuum (there is no need for a chamber of a triple point chamber and sluices), it is possible to use the equipment of a cluster target, it is possible to receive targets with a diameter of D < 20 µk from various cryogenic liquids (H2, D2, N2, Ar) with dispersion less than 1%, the high velocity of monodisperse granules(> 100m/s), exact synchronization of the target hitting moment in a beam with the moment of sensors turning on

Development of accelerating technique made possible receiving the high-energy beams of elementary particles. Interaction between such beams and cryogenic monodisperse targets will allow to solve fundamental problems of nuclear physics.

The cryogenic monodisperse target is the most perspective target for future experiment of "PANDA" [1-3]. "PANDA" is a unique experiment within the project of the new European accelerator FAIR in Darmstadt (Germany). The physical program of the experiment is research of fundamental problems of nuclear physics, finding of new extremal matter forms.

Cryogenic monodisperse targets have the following unique properties:

1. The small size of monodisperse targets – diameter is from 20 micron to 100 microns. Targets can be received from hydrogen or its isotopes, nitrogen, argon, neon, krypton and xenon.
2. High luminosity of targets and a possibility of registration of particles dispersion at angle of $4\pi$.
3. Renewability – targets pass through a beam during small time.

Cryogenic monodisperse targets represent the flow of solid monodisperse granules of the small sizes received from liquefied gas. The liquid cryogenic jet follows from the generator of monodisperse drops in the vacuum chamber. Under the influence of special perturbation the jet breaks up to drops .Because pressure in the vacuum chamber is smaller than pressure about drops surface, there is intensive evaporation of liquid. As a result drops are cooled, freeze and become solid granules. Passing through system of sluices the granules accelerate and come to the working camera where there is an interaction to an accelerating beam or laser ray. For reduction of leaking and increase of granules speed it is possible to use two and more vacuum chambers divided by sluices. After interaction with high-energy beam the granules get to the cooled trap and deposit on its walls.

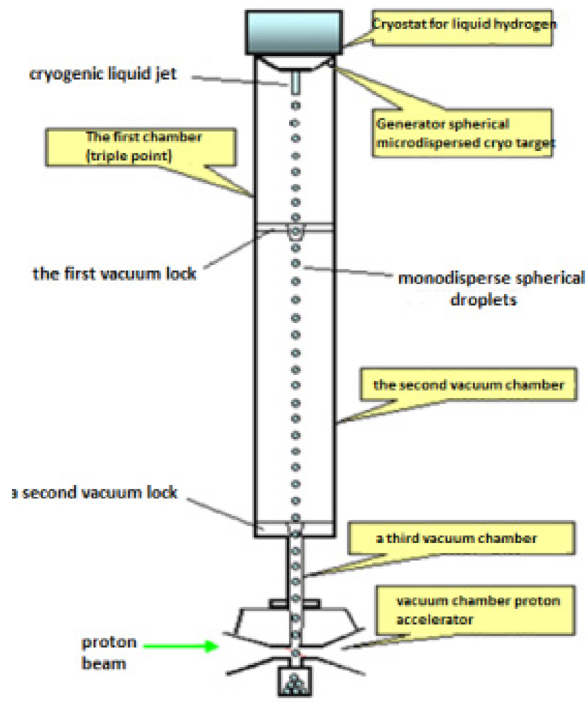


Figure 1: The detailed description cryogenic corpuscular targets.

The detailed description of the operation of installations on receiving cryogenic corpuscular targets is provided in [4-5] and fig. 1.

The important effect on stability of targets flow have sluices and especially the first sluice connecting the triple point camera to other vacuum chambers. If to remove the first sluice, not to allow to a liquid cryogenic jet to freeze and directly to send drops to the second vacuum chamber, then it is possible to simplify construction of installation and to reduce its sizes.

Operation purpose: to prove the possibility of application without sluice method of receiving monodisperse cryogenic targets.

For realization of purpose the model of the expiration of a jet to the low pressure area was created in the software PHOENICS and distribution of temperature to jet surfaces is investigated by the numerical method.



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## PROBLEM IN THE MEDIUM PHOENICS

When the geometric calculations and temporary space is divided into a finite number of small control volumes, with the help of the grid in the Cartesian coordinate system. PHOENICS automatically places the system of differential equations in a conservative system of algebraic equations in accordance with the selected grid. "Conservatism" of the system of algebraic equations means that when it is receiving the physical meaning of the original differential equations persists.

It is known that the differential equations that describe the processes of heat and mass transfer and fluid dynamics are subject to a generalized conservation law [6]. For the state variable F generalized differential equation takes the following form:

$$\frac{\partial}{\partial \tau}(\rho \Phi)+\frac{\partial}{\partial x_i}(\rho v_i \Phi)=\frac{\partial}{\partial x_i}\left(\Gamma_\Phi \frac{\partial \Phi}{\partial x_i}\right)+S_\Phi \qquad (1)$$

where: $t$, $x_i$ – temporal and spatial coordinates, $\rho$ – density, $v_i$ – the components of the velocity vector, $\Gamma_\Phi$ – transfer coefficient (eg, $\Gamma_\Phi$ – turbulent viscosity coefficient, thermal conductivity, diffusion, etc.), $S_\Phi$ – source term. In particular, $S_\Phi$ may include inflow (outflow). In equation (1) and summation over index i. In solving three-dimensional problems $i = 1,2,3$.

Construction of a discrete analogue to the type of equation (1) was based on control volume method. The computational domain was divided into a number of non-overlapping control volumes so that in one control volume contained only one anchor point.

The differential equations are integrated by the control each volume. To calculate integrals used piecewise profiles that describe the variation of the function F between nodes [7]. Practice has shown that the best in terms of accuracy and efficiency in the numerical implementation are polynomial profiles.

## RESULTS OF PAYMENTS

Numerical calculations were carried out changing the temperature of liquid jets of hydrogen, nitrogen and argon for jet length and the radius of the jet depending on the diameter, speed, temperature and initial jet pressure in the working chamber. The results of some calculations are presented in Fig. 2–6.

Figure 2 shows the temperature change of hydrogen jet: diameter 10 µm, velocity 100 m/s, chamber pressure 100 Pa.

Figure 3 shows the temperature change of hydrogen jet: diameter 10 µm, velocity 130 m/s, 150 m/s, 180 m/s and 200 m/s, chamber pressure 100 Pa.

Figure 4 shows the temperature change of hydrogen jet: diameter 20 µm, velocity 130 m/s, 150 m/s, 180 m/s and 200 m/s, chamber pressure 100 Pa

Figure 5 presents the temperature change of nitrogen jet: diameter 5 µm, 10 µm and 20 µm, velocity 10 m/s, chamber pressure 100 Pa. Figure 6 shows the temperature change of nitrogen jet: diameter 10 µm, velocity 10 m/s, 100 m/s, chamber pressure 100 Pa.

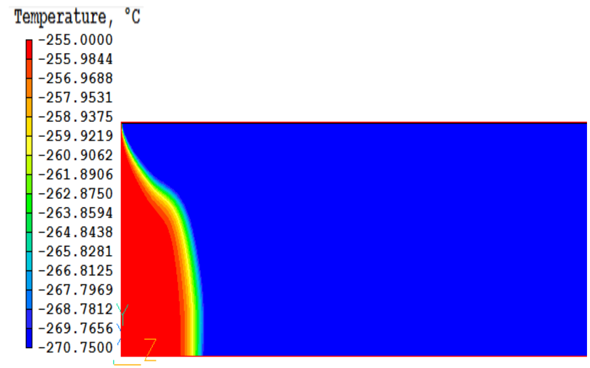


Figure 2: The temperature of the jet.

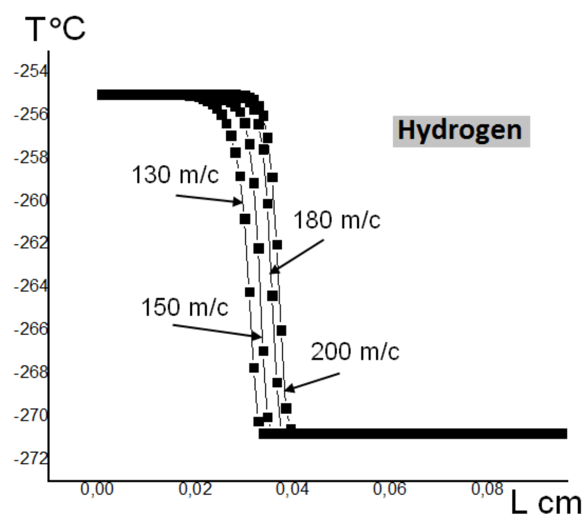


Figure 3: The temperature of the jet.

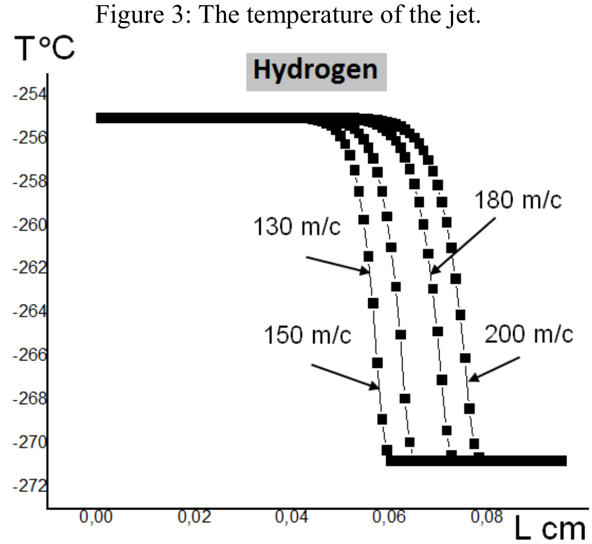


Figure 4: The temperature of the jet.

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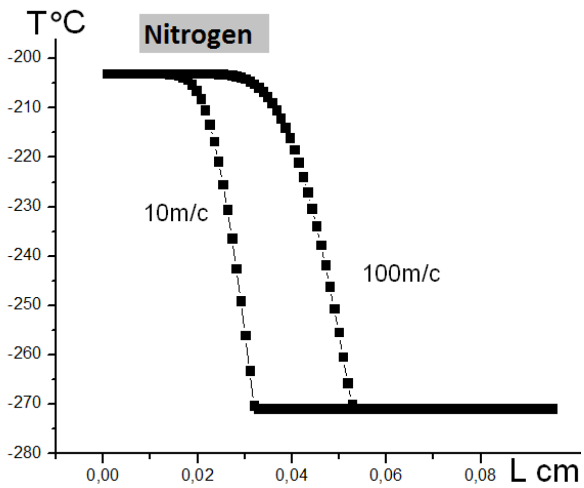


Figure 5: The temperature of the jet.

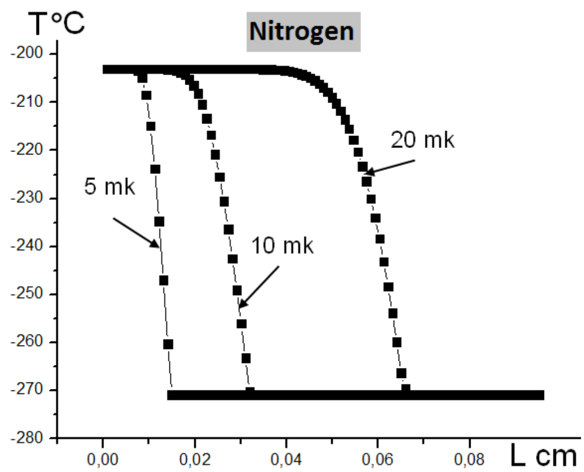


Figure 6: The temperature of the jet.

## ACKNOWLEDGMENT

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