The formation of the protonium atoms at capture of protons by the antiprotons channeled in hydrogenous crystals

M.V. Maksyuta* [1], **V.I. Vysotskii*** [2]

* Department of Radio Physics, Electronics and Computer Systems, Taras Shevchenko National University of Kyiv, 64/13, Volodymyrska Street, City of Kyiv, Ukraine, 01601

Synopsis There have been substantiated the possibilities of protons catch from hydrogenous crystal lattices by the orientation moving antiprotons resulted in the origin of exotic moving protonium atoms. It has been shown that these processes have resonance character regarding the antiprotons velocities.

The traditional method of protonium pp^-, exotic atoms obtaining is based on the mixture of protons and antiprotons in special traps – "nests" (see, for example, [1]). Protonium atoms got in such a way are hard to bring out of these traps for further investigation and usage. The given paper proposes to use the protons (localized in hard-packed hydrogenous axes) capture effect in a force field of antiprotons, moving orientationally at v velocity along the same axes. After such a capture the originating pp^- atoms may leave the crystal. Evidently, such crystals are specific nature traps or, in other words, the reservoirs of protons oscillating around their equilibrium positions in lattice.

In [2] it was conducted the calculation of the capture probabilities of these protons in LiH crystal in various quantum states of forming protonium atoms continuing their motion in the channeling regime with velocity $v' = v/2$.

The given paper deals with the analogous calculation on the basis of non-stationary theory of perturbations with the use of wave functions $\psi_k^0(\vec{r},\vec{r}',t) = \frac{1}{\sqrt{h}}\psi'(\vec{r}')\psi_k(\rho)\exp\left[-i(\varepsilon'+\varepsilon_k)t/\hbar\right]\cdot$ $\cdot\exp\left[i\left(Mvz - Mv^2t/2\right)/\hbar\right]$ of the system "proton in $\psi'(\vec{r}')$ state with ε' energy plus antiproton in $\psi_k(\vec{\rho})$ state of axial channeling with the transverse energy of ε_k motion" and also a wave function of quantum state of protonium free moving atom $\Psi_n^1(\vec{r},\vec{r}',t) = \psi_{nlm}(\vec{r})\exp\left\{\left[2Mv'(z-v't) - E_n\right]/\hbar\right\}\cdot$ $\cdot\psi_{nlm}(\vec{r})\exp\left[i\vec{p}_\perp\vec{\rho}/\hbar\right]/\sqrt{Sh}$ (here M – the proton mass). The mechanism of proton capture is connected with Coulomb proton-antiproton interaction. There were calculated the capture probabilities of proton $P_n(v)$ capture in various quantum states of the channeling antiproton. In Figure 1a it was schematically illustrated the process of proton capture by the channeling antiprotons resulted in protonium origin. The Figure 1b shows the resonance dependences of $P_n(v)$ capture probabilities in relative units $\mu = v/v_{n\max}$ and $P_n(\mu)/P_{n\max}$ ($v \sim 10^8$ cm/c, $P_{n\max} \approx 10^{-3} \div 10^{-2}$).

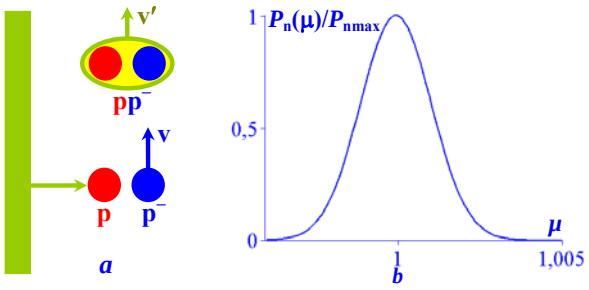

Figure 1. (a) – schematic presentation of the process of a proton capture by the channeling antiproton with the formation of protonium atom, (b) – 2D-plot of the function of capture probability of the proton by the antiproton.

It should be noted that the processes of proton captures on the highly excited long lived quantum levels carried out with high probability.

The given report also deals with the analysis of the processes of protons capture in various quantum states of the channeling antiprotons on the basis of the theory of the sudden perturbations [3]. Besides, the probabilities of the capture in these states have a resonance character at high velocities.

References

[1] E. Klempt *et al* 2002 *Phys. Rep.* **368** 119
[2] N.V. Maksyuta *et al* 2016 *Theses of the Reports of VII International Conference Charged & Neutral Particles Channeling Phenomena*, Sirmione-Desenzano del Garda, Italy 68
[3] A.S. Davydov 1965 *Quantum Mechanics*, Pergamon Press

[1] E-mail: maksvuta@univ.kiev.ua
[2] E-mail: vivysotskii@gmail.com