METHODS FOR ACHIEVING AND RECORDING SUPERLIGHT VELOCITIES FOR PARTICLES AND RADIATION IN ACCELERATORS
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Unlike classical physics, where there are no restrictions on the maximum speed *V* of objects, the special theory of relativity (SRT) sets a fundamental limit $c = 3 \cdot 10^8$ m/s - the speed of light in vacuum. Despite the centuries-old history of checking other SRT consequences, the upper speed limit has not been established reliably. Direct measurements of the velocity by the time-of-flight method (TOF-detectors), as a rule, are performed for ions, far from the light barrier - at a momentum p <1 GeV/*c* per nucleon, when the classical $V = p/m < c$ For ultrarelativistic particles, direct measurements are not made with TOF cameras. And in rare experiments, interpreted as confirmation of the threshold *c*, superluminal velocities have been revealed.

One of the first experiments of this kind was the Bertozzi experiment [1]. With an increase in the energy *W* of electrons from 0.5 to 15 MeV, their velocity, measured on the flight base $L = 8.4$ m by the time of flight *T*, varied from $2.6 \cdot 10^8$ to $3.0 \cdot 10^8$ m/s, not exceeding c ... In fact, only the average velocity $V = L/T$ of an electron bunch was measured in a linear accelerator. Since along the length L of the accelerator the velocity increased from V_1 to V_2, and at $W = 15$ MeV the velocity of electrons at the entrance to the accelerator $V_1 << c$, then at the exit the velocity $V_2 > V = c$. Thus, Bertozzi's experiment was the first to confirm the superluminal velocity of relativistic electrons. The condition of synchronism between particles and the field was fulfilled in [1], since in the accelerating waveguide, in addition to the fundamental mode $V_ф \approx c$, TM-wave modes with the phase velocity $V_ф = V > c$ were also excited.

From modern experiments known experiment "OPERA" on the measurement of the neutrino velocity, exceeding *c* by $\Delta V \sim 7.5$ km/s, and the "MINOS" experiment - $\Delta V \sim 10$ km/s [2]. An excess of the neutrino velocity was discovered in 1976 in the Fermilab laboratory [3]: the neutrino velocity exceeded the speed of c kaons by $\Delta V \sim 10$ km/s. In the supernova SN 1987A, the registration of a series of neutrinos 7 hours before the outburst corresponded to an excess of *c* by $\Delta V \sim 1$ km/s [2]. Thus, despite disputing the results of "OPERA", other experiments leave open the question of the neutrino speed. The closeness of the neutrino speed to the speed of light and the independence of *V* from the neutrino energy can also mean the registration of electromagnetic radiation of ultrahigh penetrating power and frequency. The excess follows from Ritz's ballistic theory, according to which the source imparts its speed to light.

Superluminal particles have also been identified by their Cherenkov radiation [4], and in extensive air showers (EAS) of cosmic rays [5]. At $V \approx c$, the zenith angle $\theta_т = \arcsin(V\Delta t/2b)$ measured from the difference in the moments Δt of registration of the EAS front was systematically smaller than the directly measured $\theta_э$ - from the spot shape (with semiaxes a and b, $\cos\theta_э = a/b$) of triggered detectors, according to the method Fly's Eye, etc. Estimates of $\theta_т$ and $\theta_э$ will coincide at $V = 2b\sin\theta_э/\Delta t > c$. The obtained characteristics of the Cherenkov, synchrotron and undulator radiation also agree with the classical $V = p/m > c$, with a ballistic dependence of the speed of light on the speed of the source [6, 7]. Experiments [8] do not refute this either when comparing the speed of electrons and their radiation. Their synchronous registration means the proximity of speeds, but not $V = c$. In ballistic theory, at a momentum p = 11 GeV/s, the velocity of electrons V and their emission c' are also close: $V \approx 22000c$ and $c' = c + V \approx 22001c$ [9].

In large cyclic accelerators $V > c$ follows from direct estimates $V = Lf$, where $L \sim 1000$ m is the length of the accelerator ring, $f \sim 10$ MHz is the frequency of the accelerating field synchronous with the rotation of particles [9, 10]. As a rule, $V = Lf$ coincides with the classical $V = p/m \approx \gamma c$, where $\gamma \approx p/mc$ is the measured Lorentz factor. In SRT, $\upsilon = Lf_1 \approx c = V/q$ is considered, assuming the particle rotation frequency f_1 is q times lower than the frequency f of field oscillations. Hence, $q \approx \gamma$ is a typical relation, mysterious from the point of view of SRT.

In small-radius accelerators, even for $\gamma >> 1$, $q = 1$ and $V = Lf = c$. But if the particles rotate with a frequency n times higher than the frequency of the accelerating field, the true velocity is $V = \gamma c > c$. Such modes are possible because oscillations of the field $E(t)$ of the accelerating resonator impart different energies to particles in the accelerating and decelerating phases of the field due to variations in the particle velocity [9]. And the field $E(t) = \Sigma a_n \cos(2\pi nft + \varphi_n)$ contains, in addition to the fundamental frequency f, harmonics with amplitudes a_n, numbers $n = 100$ and higher, accelerating synchronous particles with revolution frequencies nf. For bunches flying in orbits of different radii with frequencies nf, the total signal $S(t)$ from the detectors can be roughly represented by the superposition $S(t) = \Sigma b_n[1 + \cos(2\pi nft + \theta_n)]$, where b_n is the amplitude, θ_n is the phase, depending on the equilibrium phase of the bunch and the detector distance. The signal $S(t)$ has the form of pulses of frequency f. The effect is similar to the generation of short laser pulses of frequency f upon mode locking nf of the cavity. At $V > c$, the effect is also possible in linear accelerators: modes of different velocities $V_ф$ are excited in the waveguide, accelerating synchronous bunches. And their signal $S(t)$ corresponds to $V \leq c$.

Direct measurements of the velocity will make it possible to check SRT and increase the efficiency of accelerators when generating an accelerating field in the microwave and THz ranges exactly at synchronous frequencies *nf*. From the ballistic theory at $V >> c$, the efficiency of accelerators can also be increased by taking into account the dependence of the accelerating force $F \approx F_0(V/c)^2$ on the velocity V of the charge [9]. Confirmation of the superluminal speed of particles and radiation will increase the efficiency of accelerators for use in devices for long-range space communications and superluminal space transport.

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