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ANALYSIS OF THE ANOMALOUS CHERENKOV RADIATION OBTAINED IN THE RELATIVISTIC LEAD ION BEAM AT CERN SPS

A.S.Vodopianov, V.P.Zrelov, A.A.Tyapkin

The first experimental indication of the Cherenkov radiation caused by superluminal particles – tachyons – is informed about. This conclusion has been made on the basis of the analysis of the anomalous Cherenkov radiation when the beam of relativistic lead ions of SPS accelerator at CERN was passing through a gas radiator.

The investigation has been performed at the Laboratory of High Energies, the Dzhelepov Laboratory of Nuclear Problems, and the Laboratory of Particle Physics, JINR.

Анализ аномального черенковского излучения, полученного на пучке релятивистских ионов свинца SPS CERN

А.С.Водопьянов, В.П.Зрелов, А.А.Тяпкин

Сообщается о первом экспериментальном указании на существование сверхсветовых частиц — тахионов, основанном на регистрации и анализе аномального черенковского излучения, возникшего в газовом радиаторе при прохождении пучка релятивистских ионов свинца ускорителя SPS ЦЕРН.

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APPARATUS

The Cherenkov radiation caused by relativistic lead ions was studied at SPS CERN [1]. The Cherenkov gas detector was placed in the H2 beam line in the location of NA49 set-up between the large time-projection chamber and the barrel hadron calorimeter [2]. The general layout of the detector is shown in Fig. 1. A beam of $^{208}Pb^{82+}$ ions with the energy of 157.7 A·GeV was going along the axis of the Cherenkov detector. The beam size in the location of the Cherenkov detector was about 3 mm in diameter. The entrance window in the aluminium flange had a diameter of 20 mm and a wall 0.4 mm thick. The Cherenkov light emitted in the radiator (its length along the optical axis is 405 mm) got into the objective of a photocamera after its reflection in the mirror inclined under 45 degree angle relative to the axis of the radiator. The inner surface of the detector tube was covered by soot to avoid light reflections. The «Zenit–E» photocamera with the «Helios-40» objective (the light power 1:0.85; focus distance $f = 85$ mm) and a black-white negative photofilm (the sensitivity of

20 units of GOST which corresponds to ISO 23/14) were used in the experiment. The lens was tuned for infinity to obtain the ring image for the corresponding cone of the Cherenkov radiation.
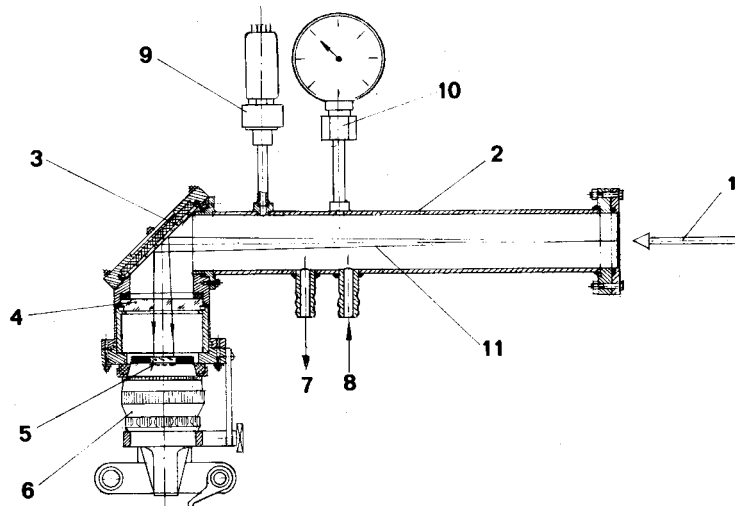

Fig. 1. Layout of the gas-filled Cherenkov detector: 1 — collimated beam of lead ions; 2 — gas radiator tube 60 mm in diameter; 3 — mirror (the aluminium layer sputtered on the glass plate); 4 — outlet window; 5 — «Helios-40» objective and a «Zenit-E» camera; 6 — diffraction lattice (not installed in this experiment); 7 — vacuum system connector; 8 — gas connector; 9 — vacuum meter; 10 — gauge; 11 — direction of the Cherenkov radiation

EXPERIMENTAL RESULTS

The results presented in this paper based on the analysis of three photoshots which were made with the Cherenkov detector filled with air at the atmospheric pressure. In each case the accumulated statistics was about 10^7 lead ions passed through the detector. One of these pictures is shown in Fig. 2. A bright narrow ring of the Cherenkov radiation seen on the picture is caused by relativistic lead ions. Two other narrow rings located inside and outside the ring caused by the beam have the other origin that will be discussed in another paper. Besides, in this picture we have found hardly noticeable narrow Cherenkov radiation rings of the particles flying out under small angles to the direction of the beam.

The calculation of the velocity of these particles has shown that it corresponds to those of particles moving faster than the light velocity in the vacuum. The large Cherenkov radiation ring shown with an arrow in Fig. 2 corresponds to the particle velocity approximately equal to $\beta \approx 1.0008$. The ring diameter of its radiation is approximately two times larger than the ring diameter of the proton radiation at the velocity of motion $\beta \to 1$. For the better visual representation of this photoshot (Fig. 2), it was scanned by means of a specialized technique of image transformation which provides extraction of 3 rings more in the same photoshot (see Fig. 3).
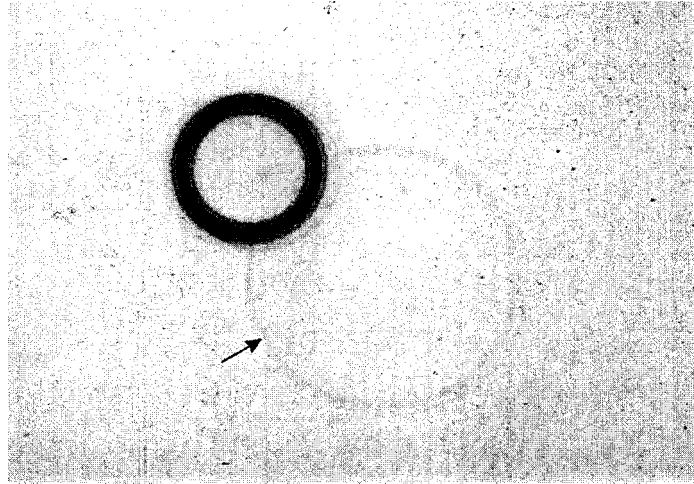
Fig. 2. Example of the observed anomalous Cherenkov radiation ring (indicated by pointer)
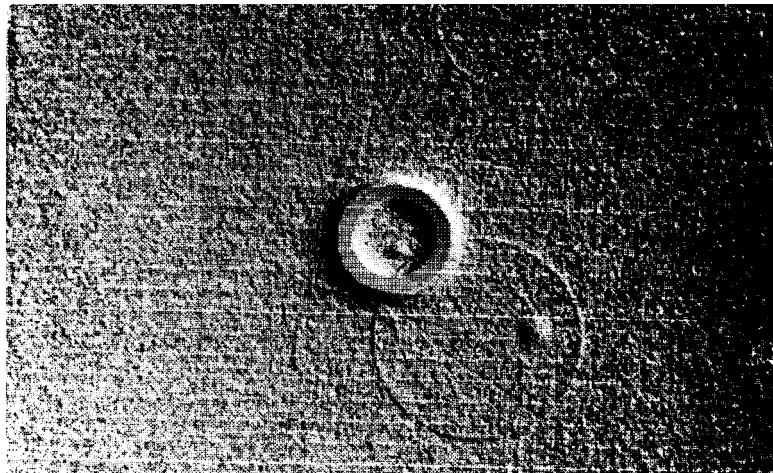

Fig. 3. The image of the photoshot of Fig. 2 obtained by means of a specialized technique of image transformation

The intensity of the beam Cherenkov radiation was measured and compared with the intensity of the radiation concentrated in anomalous ring. It was shown that the radiation energy concentrated in the anomalous ring is quite large and approximately 0.01 of the energy of the Cherenkov radiation from 10^7 lead nuclei which is about 2.7 erg.

Totally, seven rings* of the anomalous radiation have been found in the three photos. To extract them while making prints it was required to match an exposure individually. A

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*3 rings presented by their arcs only.

mnemonic scheme of locations of rings in these photographs is shown in Fig. 4. The general numeration for them is given as well. Thick circles in photoshots *a, b, c* give the location of the Cherenkov radiation ring of the lead ion beam in the air.
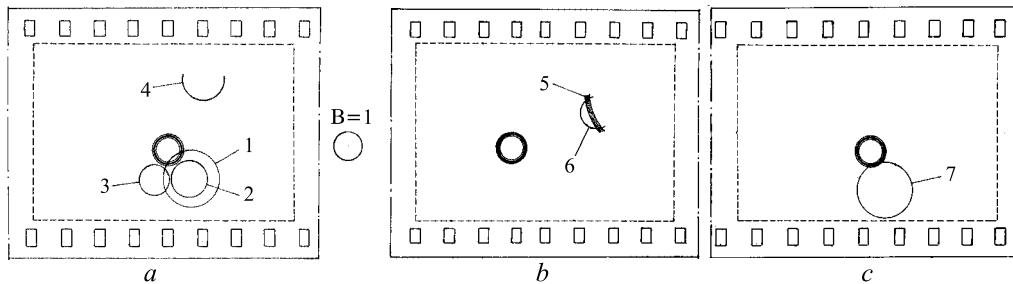

Fig. 4. Layout of the anomalous Cherenkov radiation rings

The rings were analysed using the standard expression $\cos \theta = 1/(n \cdot \beta)$. The procedure of the calculation of the particle velocity was as following. According to the calibration of our objective, the 1mm distance on the film corresponds to 40 angle minutes. So the radius of the ring measured on the film could be transformed into the angle of the Cherenkov radiation taking into account such ratio. The velocity of the particle is defined as $\beta = 1/(\cos \theta \cdot n^{\mathrm{air}})$ for the known refraction index of the air $n^{\mathrm{air}} = 1.000263$ ($\lambda = 546$ nm) at $P = 729$ mm Hg and $t = 20°$C. The uncertainty of β depends on the accuracy of measurement of the mean diameter of the ring. For example, in case of the ring No.1 the accuracy of the diameter measurement is equal to ± 0.02 mm and the uncertainty in β is $\pm 1 \cdot 10^{-5}$. For other rings the uncertainty in β is larger due to the lower intensity of the detected radiation and because of the fact that some rings like Nos.5 and 6 are presented on the film by their arcs. The azimuth distribution of rings is rather uniform (7 rings are located in the first, third and fourth quadrants).

Table. Kinematical parameters of the anomalous Cherenkov radiation rings

Ring No.	Mean diam. (mm)	Radiation angle (degree)	α^* (degree)	β
0	3.79 ± 0.01	1.263 ± 0.003	0	$0.999979527 \pm (2 \cdot 10^{-7})$
1	7.82 ± 0.02	2.607 ± 0.006	3.3	$1.00077 \pm (1 \cdot 10^{-5})$
2	5.42 ± 0.04	1.807 ± 0.013	3.3	$1.00023 \pm (1 \cdot 10^{-5})$
3	3.99 ± 0.2	1.33 ± 0.07	3.1	$1.00001 \pm (3 \cdot 10^{-5})$
4	5.16 ± 0.2	1.72 ± 0.06	6.2	$1.00019 \pm (3 \cdot 10^{-4})$
5	17.10 ± 0.6	5.7 ± 0.2	13.6	$1.0047 \pm (4 \cdot 10^{-4})$
6	4.36 ± 0.2	1.46 ± 0.06	8.4	$1.00006 \pm (3 \cdot 10^{-5})$
7	7.80 ± 0.2	2.60 ± 0.01	3.0	$1.00076 \pm (2 \cdot 10^{-5})$

*The slope angle of the particle path towards the beam direction.

The kinematical parameters for each ring of the anomalous radiation are given in the Table (points *1–7*), namely: the mean ring diameter, radiation angle (θ), the axis angle (α)

of the radiation cone relative to the direction of the lead ion beam and a relative velocity of the hypothetical particle expressed in the units of the light velocity in the vacuum. For comparison the first line of the Table gives the parameters for the Cherenkov radiation ring caused by the $^{208}Pb^{82+}$ beam.

DISCUSSION

Since we are speaking about such an unusual radiation, it is reasonable to discuss other possible causes of the observed effect.

First of all, it is necessary to consider an optical transformation of the intense Cherenkov radiation ring from the beam into the reflected ring of the increased diameter. We have considered the possible imitation of the observed anomalous rings as a result of the reflection of the original Cherenkov radiation cone from the bulging surface of the objective (radius of curvature is about 8 cm) and the following reflection from the Cherenkov detector outlet window (see Fig. 1). Our calculations show, that such an effect can take place but we shall observe very eroded ring with much lower intensity of radiation (three orders of magnitude lower). In our experiment we did not observe any very low-intensity eroded rings.

The same Cherenkov detector that we were using in our studies was exposed in the electron beam of VEPP-3 accelerator at Novosibirsk [3]. The aim of the studies was the search for the Cherenkov radiation in gases. Besides conventional Cherenkov rings from the scintillation in gases, the much larger diameter rings were observed. The Cherenkov radiation angle for these rings was larger than the maximum Cherenkov angle for a particular radiator. These rings were rather wide and exactly centred relative to the axis of the tube of the Cherenkov detector, i.e., they were located in the centre of the frame. The diameters of the rings were not dependent on the pressure of gases (e.g., Helium) in the detector. So these rings were interpreted, without any doubt, as reflections of the electron beam Cherenkov light from the detector tube.

It is necessary to stress again that during the preparation of the experiment the inner surface of the detector tube was covered by soot to prevent from the optical reflections of the Cherenkov light.

The second possibility of the imitation of the «superluminal particle» could be the Cherenkov radiation cone from the beam during its fall on the border of two media. As was shown in [4] at the angle of the incidence $\Psi = 90°$, «the super light source» has the velocity $V_0 = c/(n \cdot \sin \theta)$, where θ is the Cherenkov radiation angle. In case of the fall of the particle on the mirror at the angle of incidence $\Psi = 45°$, as it is in our experiment, the velocity V_0 is equal in the range of $\sim 1.41c$ to $\sim 45c$ (c — velocity of light in vacuum). But velocities detected in our experiment exceed the velocity of light c only by a small value ($\Delta\beta_{max} \approx 5 \cdot 10^{-3}$).

The fluorescence of the atoms and molecules of air excited by the lead nuclei was considered as a source of the imitation of the registered rings. This fluorescence of the atoms along the beam, of course, exists, but it is isotropic and its transformation is not imaginable into several narrow rings of large different diameter ($\theta > \theta_{max}$) with the corresponding radiation cones on different angles.

Thus, it is impossible to find a concrete reason of imitation of the found superluminal motion effects in our experiment. So our experimental data and the results of their analysis

are in good agreement with the hypothesis on the existence of superluminal particles — *tachyons* [5].

The estimate of the value of the intensity of the Cherenkov radiation concentrated in anomalous rings (about 0.03 erg) shows that only a hypothetical particle having an exotic magnetic charge of 400 minimal charges of Dirac monopole could emit the Cherenkov radiation of such a large intensity.

We estimated the production cross section of the superluminal particles on the air nuclei while the lead ion beam with the energy of 157.7 A·GeV is going through our detector. Having seven registered anomalous rings of the Cherenkov radiation which may represent independently produced superluminal particles, it is possible to give a maximal estimation of the superluminal particles production cross section in nucleon-nucleon collisions, which is about 10^{-31} cm^2.

CONCLUSION

According to some theoretical predictions, the tachyons (if they exist) are stable particles but lose the entire energy extremely fast (accelerating to the velocity $V \to \infty$) in the wide range of frequency from 0 to $E/\hbar$. As it was shown in [6] the energy loss of the tachyon (if its size is $\hbar/(m \cdot c) = 3.8 \cdot 10^{-11}$ cm) is of the order of 10^2 TeV/cm. Thus it is preferable to search for tachyons via the Cherenkov radiation at the time of their creation in the transparent media (see e.g., [7]). The confirmation of the existence of superluminal particles in Nature will prove the fundamental theoretical ideas of «meta» relativism [8].

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