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# Crystal-assisted extraction of Au ions from RHIC and application of the Au beam for the search of anomalous Cherenkov radiation

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**Abstract**

It is proposed to perform an extraction of the gold ion beam from Relativistic Heavy Ion Collider at BNL (USA) with the highest energy of 100 A GeV. The beam extraction is to be done by a bent Si crystal. The following scientific program could be performed on the extracted gold ion beam: a search for superluminal particles – tachyons; a study of the Cherenkov double photon radiation; a measurement of the absolute intensity of heavy ion Cherenkov radiation; a study of the ionization loss of the heavy ions; a study of the Cherenkov radiation in anisotropy media.


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## 1. Introduction

The discussions of particles moving with the superluminal velocities were traced back to Thompson [1], Heavyside [2] and Sommerfeld [3]. A number of theoretical papers discussed various aspects concerning the existence of tachyons [4–10]. Some experiments were proposed to search for tachyons in non-accelerator fields [11,12]. A few experiments were performed on accelerators [13–15] in the past but without success. The first experimental indication on the detection of the Cherenkov radiation of tachyon was obtained in CERN experiment [16] in 1998.

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It is proposed to carry on a wide program of Cherenkov radiation research in the extracted gold ion beam of Relativistic Heavy Ion Collider (RHIC, BNL, USA). Various aspects of well-known Cherenkov radiation are not studied yet. As an example we can mention the discovery of the interference of two transition radiations near the threshold of Cherenkov radiation in helium [17]. Apart from the tachyon search we intend to perform a study of the Cherenkov double photon radiation, a measurement of the absolute intensity of the Cherenkov radiation, a study of the ionization loss of the heavy ions and a study of the Cherenkov radiation in anisotropy media. The beam extraction will be made with a bent crystal.

## 2. The extraction of the gold ion beam from the RHIC ring

The crucial point in the realization of our program is an extraction of gold ion particles confined in the beam halo. There is a robust technique of bent crystal channeling [19], which is under development also at RHIC [20–23] and which we would like to use for this purpose.

For the efficient use of the bent crystal it should be installed in the place, where the maximum of the amplitude function is achieved. According to [30,31] this occurs at the insertion at about 35 m from the interaction point (IP) (Fig. 1, top curve). At this position the horizontal amplitude function is equal to $\beta_x = 1223$ m and vertical $\beta_y = 366$ m. At the top RHIC energy the Lorentz factor of the gold ion beam is $\gamma = 108.4$, the normalized emittance after 10 h store is $\varepsilon_N = 40\pi$ mm mrad. Therefore, the beam size and angular divergence in the horizontal and vertical planes can be calculated as

$$\sigma_x = \sqrt{\frac{\beta_x \varepsilon_N}{6\pi\gamma\beta}} = \pm 8.7 \text{ mm}, \quad \sigma'_x = \sigma_x/\beta_x = \pm 7.1 \ \mu\text{rad}, \tag{1}$$

$$\sigma_y = \sqrt{\frac{\beta_y \varepsilon_N}{6\pi\gamma\beta}} = \pm 4.7 \text{ mm}, \quad \sigma'_y = \sigma_y/\beta_y = \pm 13 \ \mu\text{rad}. \tag{2}$$

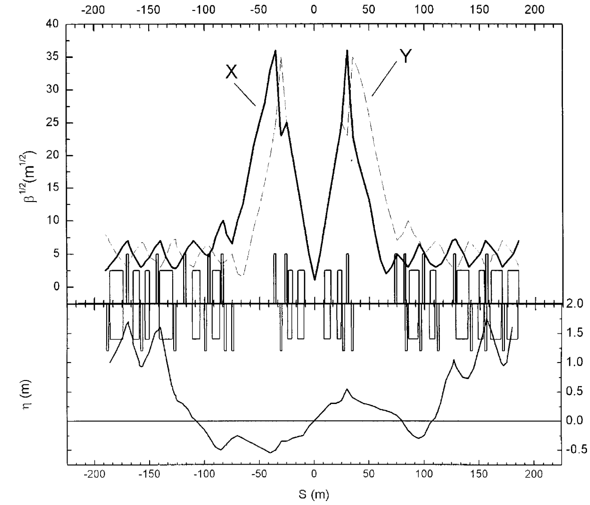


Fig. 1. Betatron and dispersion functions in the insertion region. Rectangles along $x$-axis show the magnets position.

We attempt to extract from the RHIC ring the gold ions sitting at the beam halo, that is, having a betatron amplitude $\geqslant 5\sigma$. Therefore, the position of the crystal is fixed at the radial distance $r = 4.2$ cm from the equilibrium orbit. The channeled gold ions should be bent by an angle of the order of 25 mrad, which is currently defined by the following considerations:

- The available space between the quadrupoles Q3 and Q4 is about 40 m.
- The external diameter of the vessel containing the quadrupole Q4 is around 610 mm (see [30], p. 148).
- Assume the external diameter of the Cherenkov detector is 800 mm and its length is around $l = 1$ m. If the detector is placed at a distance of $L = 40$ m from the crystal one should have a beam bending angle of

$$\theta = \frac{l}{L} = 25 \text{ mrad}. \tag{3}$$

Therefore, the crystal should provide such a bending. In order to estimate the intensity of the extracted gold ion beam we made the following assumptions:

- The beam stored in the RHIC ring consists of 57 bunches, $10^9$ gold ions per bunch.

- During collider operation the halo is being fed continuously by the ions scattered by various mechanisms out of the beam core. As an estimate for the beam lifetime we assume that in 6 h one-half of the beam is lost. This means that the halo is supplied by $57 \times 10^9/(6 \times 3600) \times 0.5 = 1.3 \times 10^6$ ions/s.
- The extraction efficiency of the bent crystal, assuming that the bending angle is 25 mrad and the crystal is aligned to the beam envelope at $5\sigma$, has been simulated by Monte Carlo code CATCH [24] and found to be ≈38%. Then we expect the extracted beam to have intensity of $1.3 \times 10^6 \times 0.38 = 0.5 \times 10^6$ ions/s. At the exit of the bent crystal the extracted beam will have the following parameters presented in Table 1.

The extraction efficiency of 38% is for a single-pass mechanism, obtained in the assumption of a parallel incident beam and a perfect surface of a crystal. This is not unrealistic: in an earlier simulation [20] we used the results of some diffusion simulations for Au ion halo at RHIC where the halo ions were irradiating a crystal within 20–40 μm from its edge (so the surface irregularities must be much smaller than this), with angular divergence being well within the critical channeling angle of 10 μrad. Multi-pass mechanism will not work in our case (Au ions, 8 cm crystal). There are several reasons for a suppression of the multi-pass mechanism: certainly strong losses of Au ions in 8 cm of Si crystal, and rather strong multiple scattering in inefficient encounters with the crystal (so even for protons the multi-pass effect would be poor in the considered case).

Table 1
The parameters of the gold ion beam (at the exit of the bent crystal) extracted from RHIC

| | |
|---|---|
| Gold ion beam kinetic energy (A GeV) | 100 |
| Beam energy spread ($\times 10^{-3}$) | $\pm 3.0$ |
| Beam size | $\sigma_x = 0.1$ mm, $\sigma_y = 1.4$ mm |
| Beam divergence | $\sigma'_x = \pm 5$ μrad, $\sigma'_y = 1.3$ μrad |
| Beam intensity per second | $\sim 0.5 \times 10^6$ ions/s |
| Number of bunches | 57 |
| RMS length of bunch (m) | 0.25 |
| Bunch length (m) | 0.93 |

The first experimental data is coming from the RHIC crystal collimation experiment where channeling was successfully observed [23] with beams of Au ions and polarized protons circulating in the Yellow ring of RHIC.

The curvature of 8-cm Si crystal with 100 GeV/u (250 GeV/Z) Au ions is 0.78 GeV/cm which is 15–20% of the critical one for Si(1 1 0). This is rather strong curvature, and it leads to a substantial loss in the efficiency of crystal channeling due to centrifugal effect and scattering on the nuclei of the crystal. These losses however were taken into account in the simulations, so the figure of 38% represents the Au ions surviving in the channeled states throughout the crystal length.

The beam energy spread is somewhat increased as compared to the original beam energy spread of $1.9 \times 10^{-3}$ for the ions channeled in the crystal. The present estimate for the ionization energy losses did not include the Lindhard–Sorensen effect [25–27]. In the same model, the simulations were done in our recent work [28] where the model was shown to be in reasonable agreement with the measurements, sufficient for our present study. Beam divergence in the horizontal plane (the plane of bending) is set by the critical angle of channeling, and equals to $\pm 10$ μrad (full width), or about $\sigma = 5$ μrad. The divergence in vertical plane for channeled ions is practically the same as for the incident particles, because the channeled ions are confined far from the crystal nuclei and experience only electronic scattering in the crystal. Beam size in the vertical direction is defined by the crystal size; for now we set it to be 5 mm full height or $\sigma_y = 1.4$ mm. If necessary, it can be reduced further without affecting the intensity of the extracted beam. The beam size in the horizontal plane at the exit of the crystal is set by the distribution of the halo ions irradiating the crystal. This parameter is a function of beam conditions. However, the beam size is a small fraction of mm, possibly 10–50 μm. In any case, the maximal possible size of the beam is set by the crystal thickness in radial direction (fraction of mm). In the Table 1 we tentatively set $\sigma_x = 0.1$ mm.

The channeled ions have no close collisions with the nuclei of the crystal; therefore the channeled (deflected) beam of fully stripped Au ions is not contaminated by other particles. In other words, if

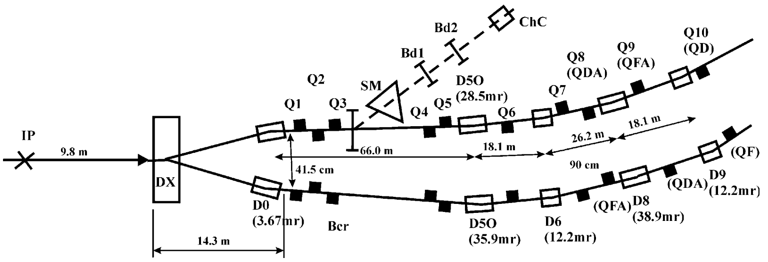


Fig. 2. Expanded layout of half-insertion. The proposed experimental setup: Bcr – bent Si crystal for beam halo extraction; Bd1, Bd2 – beam counters; ChC – Cherenkov detector; SM – sweeping magnet.

any channeled ion has a close collision that may alter its nuclear state, e.g. through electromagnetic dissociation, then such an ion will definitely be dechanneled, and therefore we will not see it in the extracted beam. Further downstream of the crystal, an interaction with material like a window of the vacuum chamber may change the nuclear states for some of ions, (see e.g. [29]).

In the case of 25 mrad bending, the crystal will have to be about 8 cm silicon. Further on we simulated extraction in the cases with bending angle reduced to 15 mrad or increased to 32 mrad, as been considered in some alternative options. Here, the efficiency was respectively increased to about 49% or reduced to 31%, with optimal crystal length being 5 or 10 cm accordingly.

There are several problems in transporting this beam from the exit of the crystal to the detector. They are as follows:

1. The extraction of the beam from the vacuum pipe. The vacuum pipe between quadrupoles Q3 and Q4 has an internal diameter $\phi_1 = 72.9$ mm and made of the stainless steel; the exterior diameter $\phi_2 = 76.2$ mm, so its thickness is 1.65 mm. Since the bent ions strike this tube's wall under the angle of 25 mrad, the path length of ions will be equal 1.65 mm times 40 or 66 mm. For gold ion the interaction length with the ferric media will be equal 28 mm [32]. Therefore, the number of the gold ion interactions is

$$1 - \frac{N}{N_0} = 1 - \exp\left(\frac{-66}{28}\right) = 0.905.$$

That is, only 9.5% of the gold ion survives after interaction with vacuum pipe. This is not acceptable and one should cure this problem.

2. The next harm comes from the multiple scattering of the gold ion beam on the wall. The beam divergence will be increased by the additional angle of ±93 μrad. It is also a big number. So the vacuum tube must be modified for our proposal. The position, where the ion beam strikes the vacuum pipe is at $l = 1.5$ m from the crystal for 25 mrad.

3. After exiting the vacuum pipe the gold ion beams travel around 40 m in the air. Then 5% of the ion beam will be lost; the beam multiple scattering angle will amount 18 μrad. Adding in quadrature the angular divergences we got $\sigma_x = \sqrt{18^2 + 7.1^2} = 19$ μrad. This value is acceptable. The possible layout of apparatus is shown in Fig. 2.

## 3. Scientific program

### 3.1. Search for tachyons

The Cherenkov radiation of the heavy ion lead beam ($^{208}Pb^{82+}$) with energy of 157.7 A GeV was studied in the experiment [16–18] at CERN SPS. One of results of this experiment was the detection of seven Cherenkov radiation rings [16] with the diameter larger than the Cherenkov ring from the ion beam. The corresponding velocity of the particle represented by the largest ring is $\beta = 1.0047$ (Fig. 3). The energy that is confined in the largest ring corresponds to about 1% of the energy confined in the Cherenkov ring of the ion beam (2.7 erg). Authors of this paper have associated the observed Cherenkov radiation rings with the

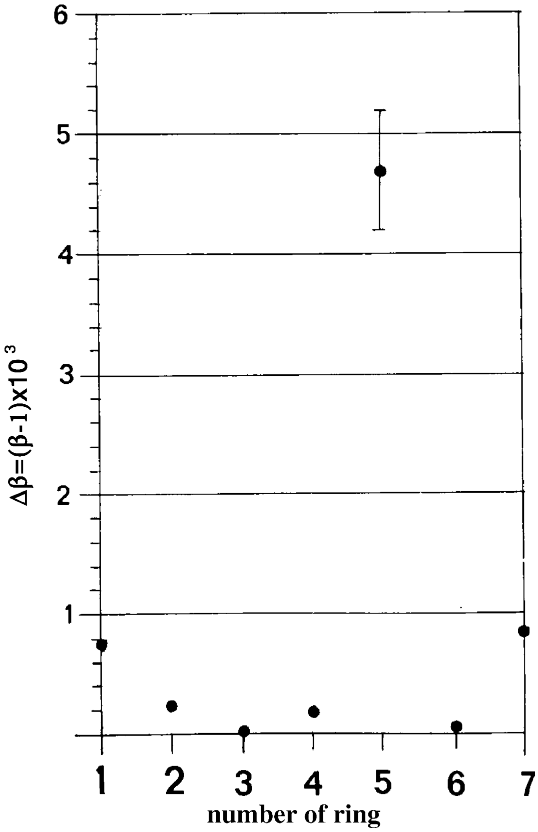


Fig. 3. The corresponding velocity of the particles for seven Cherenkov radiation rings with the diameter larger than the ring from the ion beam which were detected in [20]. The error bars for six rings are very small and lie within the black circles representing $\Delta\beta$ values.

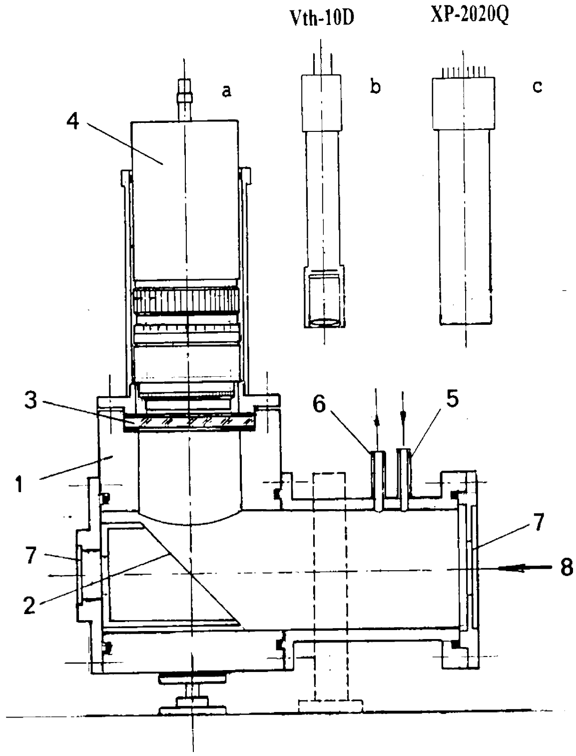


Fig. 4. The setup for the tachyon search. Three possible options of the detection elements are shown (CCD or SLR camera): 1 – body of the Cherenkov counter; 2 – mirror; 3 – interface window; 4 – CCD camera; 5 – gas inlet; 6 – gas outlet; 7 – two entrance windows of the counter; 8 – ion beam.

Cherenkov radiation of the charge superluminal particles–tachyons.

The scheme of the tachyon search in the gold ion beam with the energy of 100 A GeV is shown in Fig. 4. Various types of sensitive elements will be used in this experiment:

- SLR camera as in [16];
- CCD-camera MX916 having a quantum sensitivity of 65% at 520 nm [33]. The size of the crystal matrix is $8.7 \times 6.5$ mm ($752 \times 580$ pixels). Such a setup was used in a Cherenkov experiment in September 2000 at CERN [34]. A disadvantage of this method is that the field of vision of the objective is much smaller in comparison with the SLR camera.

In addition to the described methods, we believe it is possible to detect tachyons via light spots, stipulated by instantaneous appearance and instantaneous disappearance of tachyons. This method is based on the proposition that tachyons instantaneously lose their energy ($E_t$) in the wide spectrum range from $\omega = 0$ to $\omega = E_t/\hbar$ and fly very short distance.

According to [35] a passage of tachyons up to a finite energy of 1 eV is about $\sim 4 \times 10^{-3}$ cm. But in case the lowest limit of its finite energy is $E_f = 1$ MeV, the passage of tachyons will not exceed $\sim 10^{-9}$ cm. In such a case it is unjustified to say that the tachyon will emit radiation in a conical form. A diagram of the setup to search for tachyons using such method is presented in Fig. 5. The objective of CCD-camera should be focused to view a radiator in the beam passage.

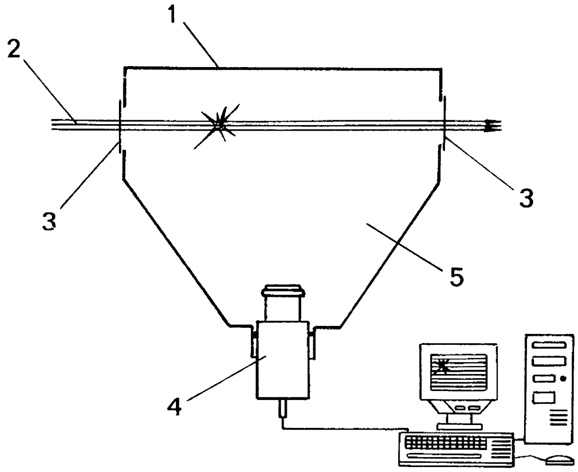


Fig. 5. Diagram of the setup to search for tachyons via light spots, stipulated by instantaneous appearance and instantaneous disappearance of tachyons: 1 – lightproof box; 2 – ion beam; 3 – thin entrance windows of the counter; 4 – video camera; 5 – air at $P = 760$ mm Hg and 20 °C.

### 3.2. Search for double photon Cherenkov radiation

Some theoretical papers [36–40] predict the existence of double photon Cherenkov radiation. This effect is of the second-order of magnitude in comparison with well-known single photon process described by the Ginzburg quantum theory [41]. In case of the single photon process, the intensity of the radiation is $\sim\alpha Z^2$, and in case of the double photon radiation process, the intensity of the radiation is $\sim\alpha^2 Z^4$, where $\alpha$ – the fine structure constant and $Z$ – particle charge. For $Z = 12$ the intensities of these two processes are comparable and at $Z = 82$ the intensity of the double photon radiation will exceed the intensity of the single photon process by $\alpha Z^2$, i.e. $\approx 50$ times. Favorable kinematical expressions of the double photon radiation process, derived from the energy–momentum conservation law, promote its effective searching. They are as follows (without $\hbar\omega/P$ term)

$$\vec{p}_1 = \vec{p}_2 + \vec{k}_1 + \vec{k}_2, \tag{4}$$

where $\vec{p}_1$, $\vec{p}_2$ – the particle momenta before and after the irradiation, $\vec{k}_1$, $\vec{k}_2$ – photon momenta. From (4) one can find

$$\cos\theta_2 \cong \frac{1}{\beta_0 n(\lambda_2)}\left[1 - \frac{\lambda_2}{\lambda_1}(n(\lambda_1)\beta_0\cos\theta_1 - 1)\right], \tag{5}$$

where $\theta_1$, $\theta_2$ – radiation angles of 1st and 2nd photons with wave lengths of $\lambda_1$, $\lambda_2$, respectively; $\beta_0$ – particle speed, $n(\lambda_1)$ and $n(\lambda_2)$ – refraction indices.

The dependence of emission angles of photons $\theta_1$ and $\theta_2$ were calculated according to (5) for the double photon radiation process. The results for the radiation for lead ions with the energy of 100 A GeV($\beta = 0.999956033$) in the air radiator at normal pressure and temperature of 20 °C are presented in Fig. 6. If spectra of the radiation of the first and second photons start from $\lambda_1 = 350$ nm and $\lambda_2 = 650$ nm respectively and the angle of the radiation of the first photon ($\vartheta_1$) lies inside of the main Cherenkov cone then the second photon emits outside of the main Cherenkov cone in the whole spectra region. If $\vartheta_2 > \vartheta_1$ then the second photon emits inside of the main Cherenkov cone.

Many authors calculated the intensity of double photon radiation, but they were considering the double photon radiation when one photon belongs to the hard (Roentgen) part of the spectra and

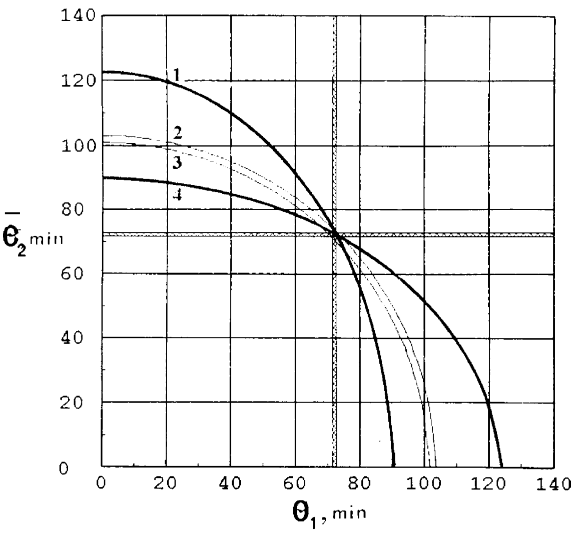


Fig. 6. The double photon radiation process. The dependence of the emission angle of the second photon ($\vartheta_2$) versus the emission angle of the first photon ($\theta_1$): 1 – $\lambda_1 = 350$ nm and $\lambda_2 = 650$ nm; 2 – $\lambda_1 = \lambda_2 = 350$ nm; 3 – $\lambda_1 = \lambda_2 = 650$ nm; 4 – $\lambda_1 = 650$ nm and $\lambda_2 = 350$ nm.

another one to the soft (optical) part of the spectra. The double photon radiation of two soft photons was considered in [36,42]. In [36] the intensity of double photon radiation is given by the expression for a number of photon pairs irradiated by a particle with a charge $Z$,

$$N(\lambda_1, \lambda_2) = \alpha^2 Z^4 \beta^2 \int \sin^2\theta_1 \sin^2\theta_2 \left(\frac{1}{\bar{\gamma}_1} + \frac{1}{\bar{\gamma}_2}\right) d\nu_1\, d\nu_2, \quad (6)$$

where $\theta_1$, $\theta_2$ are linked by the expression (5), $\bar{\gamma}_1$, $\bar{\gamma}_2$ are full widths of spontaneous radiation of atomic levels of a media and $\nu_1 = c/\lambda_1$, $\nu_2 = c/\lambda_2$.

The experimental search of the double photon radiation was indirectly performed in [43], where a deviation of the intensity of Cherenkov radiation from the $Z^2$ behavior was studied in Ne($Z = 10$), Ar($Z = 18$), Fe($Z = 26$) ion beams with energies up to 2 GeV/n.

The experimental indication on the existence of the double photon radiation was obtained at CERN SPS in Cherenkov experiment with lead ion beam of 158 A GeV [44]. The detailed study of this process (kinematical peculiarities, spectra, polarization and intensity) could be performed with the same setup layout as in Fig. 4.

### *3.3. Measurement of the absolute intensity of Vavilov–Cherenkov radiation*

Despite the fact that the Vavilov–Cherenkov radiation was discovered about 70 years ago only two experimental measurements of its important feature the absolute intensity were performed. In the first one Cherenkov has measured the absolute light output of the radiation emitted by $\beta$-particles from $Ra(B + C)$ in the interval of $\Delta\lambda = 20$ nm (from $\lambda_1 = 536$ nm to $\lambda_2 = 556$ nm) in a water radiator [45]. This intensity was $4.1 \times 10^{-4}$ erg/s mCurie. The theoretical value for his experiment (with cuts due to a slowing down of $\beta$-particles in the glass and water) is equal to $3.5 \times 10^{-4}$ erg/s mCurie. It is about 17% lower than the experimental value (with an uncertainty of the measurement of about ±25%).

In the second experiment Mather [46] measured the intensity of Vavilov–Cherenkov radiation in the region of 400–680 nm with the beam of monochromatic and monoenergetic protons with an energy of 340 MeV ($\beta = 0.68$) from the Berkeley phasotron. A glass was used as radiator ($n = 1.8796$). The measured intensity was equal to 250 photons/cm. The theoretical value, based on Tamm–Frank theory in this case, is 105 photons/cm. So, there is a large discrepancy between measurements and theoretical values.

According to Tamm–Frank theory the energy of Cherenkov light emitted by a particle with charge $Z$, velocity $\beta_0$ and with wavelength range from $\lambda_1$ to $\lambda_2$ on the unit of the passage is

$$\frac{dW}{dl} = 2\pi^2 e^2 Z^2 \frac{\lambda_2^2 - \lambda_1^2}{\lambda_1^2 \lambda_2^2} \sin^2\theta \text{ erg/cm},$$

where $e$ – electron charge, $\theta$ – Cherenkov radiation angle from the particle with velocity $\beta_0$ ($\theta = arc\cos(1/\beta_0 n)$) in the media with refraction index $n$.

For the wavelength range from $\lambda_1 = 200$ nm to $\lambda_2 = 700$ nm the energy of the radiation is

$$\frac{dW}{dl} = 1.046 n^{-9} Z^2 \sin^2\theta \text{ erg/cm}.$$

In case of the 20 cm long air radiator (at normal pressure and $t = 20$ °C) and the relativistic gold beam (100 A GeV, $\beta = 0.999956$) the energy of Cherenkov radiation is

$$W = 6.2 \times 10^{-8} \text{ erg } (6.2 \times 10^{-15} \text{ J}).$$

The irradiated energy is equal $6.2 \times 10^{-8}$ Wt if the gold beam intensity is equal to $10^7$ s$^{-1}$. The SLR camera could easily detect such intensity of Cherenkov radiation with medium sensitivity of the film and the ultraviolet sensitive objective. In case of standard optics which is sensitive to $\lambda > 350$ nm the energy of the radiation will be about $\sim 2 \times 10^{-8}$ to $3 \times 10^{-8}$ Wt. Such energy could also be detected by the photographic method. The knowledge of the used apparatus (penetration features of the objective, reflection coefficients of the deflection mirror, absolute and spectral sensitivity of the used film) and the intensity of the ion beam will give an accurate measurement of the Cherenkov radiation energy with an uncertainty of ±10%.

To obtain higher accuracy in the energy measurement it is possible to use the "Vth-10D" (and

"Carl Zeiss–Jena") thermo element. It has a quartz window and diameter of thermo element of 10 mm and a sensitivity of about $\sim$3.5 V/Wt (it could be calibrated for the better accuracy). With the power of the Cherenkov radiation of $W = 6.2 \times 10^{-8}$ Wt, the voltage output of the thermo element is about $\sim 2 \times 10^{-7}$ V, which could be measured with high accuracy. Therefore the measurement of the absolute intensity of Vavilov–Cherenkov radiation in the beam of relativistic heavy ions will allow checking the prediction of the classical theory of Vavilov–Cherenkov effect. The setup for this measurement could be as presented in Fig. 4, except the thermo element should be installed instead of the camera.

### 3.4. Measurement of ionization losses in different media by Cherenkov radiation

According to Bethe–Bloch formulae, the ionization losses (in g/cm$^2$) of particles, which are heavier than the electron, are given by

$$-\frac{\mathrm{d}E}{\mathrm{d}x} = A_0 \frac{z^2}{\beta^2}\frac{Z}{A}\left[\ln\frac{2mc^2\beta^2\gamma^2 T_{\mathrm{MAKS}}}{I^2} - 2\beta^2 - U - \delta\right], \quad (7)$$

where $A_0 = 0.1536$ MeV g$^{-1}$ cm$^2$; $z$-particle charge in electron charge units; $\beta = v/c$ ($v$ – particle velocity); $\gamma = (1-\beta^2)^{-1/2}$ – Lorenz factor; $Z$, $A$ – atomic number and atomic mass of a media; $m$ – electron mass; $I$ – average ionization potential of atoms of media; $T_{\mathrm{MAKS}}$ – maximum energy transferred by the particle to atomic electron; $U$ – correction for the coupling energy of K- and L-electron levels of atom which is important at small $\beta$; $\delta$ – media polarization correction by electromagnetic field of the particle at $\beta \to 1$ (so-called *density effect*).

Since $\mathrm{d}E/\mathrm{d}x$ is a function of a velocity, then the accurate measurement of the particle velocity will provide an accurate measurement of ionization losses. In other words, it is necessary to measure the particle velocity via Cherenkov radiation ($\beta = 1/n\cos\theta$), before and after its passage through the media. In [47] such a method was used to measure ionization losses of pions in carbon and polyethylene, where the particle velocity was measured.

In some theoretical papers on ionization losses of relativistic ions, it is predicted that non-negligible effects could exist, which will lead to the sufficient corrections to Bethe–Bloch formulae. The correction, taking into account the internal structure of nuclei is considered in [48]. This correction is important at $\gamma = 361/A^{1/3}$. For ions with $A \cong 200$, passing through the argon with $\gamma \approx 100$, the ionization losses will be decreased by about 4%. It was shown in [49], that due to the space structure of nuclei the correction to ionization losses would be of the order of the density effect. For example for $^{40}{}_{20}$Ca with the energy of 10 GeV/n this correction is about 1% and in the asymptotic limit could reach up to 25%.

For relativistic ions with $\beta \sim 1$ the relative uncertainty of measurement of ionization losses

$$\frac{\delta(\mathrm{d}E/\mathrm{d}x)}{\mathrm{d}E/\mathrm{d}x} \approx \frac{\Delta\beta}{(1-\beta)}\cdot\frac{1}{\Sigma},$$

where

$$\Sigma = \left[\ln\frac{2mc^2\beta^2}{I(1-\beta^2)} - \beta^2 - \frac{U}{2Z} - \delta\right]$$

from (7).

In case the threshold Cherenkov counter is used to measure the velocity of ions, the uncertainty of this measurement $\Delta\beta = \Delta n = K\Delta\bar{p}$. So $\Delta\beta$ is determined by the accuracy in the determination of gas pressure in the counter, when the efficiency of the detection of the ion is equal to 0. For such a purpose, it is better to measure directly the refraction index with the gas interferometer. If the accuracy $\Delta\beta \sim 10^{-6}$ for $\beta = 0.999956$ and $\Sigma \sim 10$, the relative uncertainty in ionization loss measurement is about 0.2–0.3%. So the ionization potential of different media could be measured with the uncertainty of about 2–3%. For such a measurement it is possible also to determine the velocity of ions via an interferometer picture of the Cherenkov radiation as in [34]. The experimental setup could be as in Fig. 4 (including monitor counters), but a photo multiplier should detect the Cherenkov radiation. The threshold dependences should be measured with the absorber and without it.

### *3.5. Study of Vavilov–Cherenkov radiation in anisotropy media*

The study of Vavilov–Cherenkov radiation in anisotropy media was performed early in a proton beam with an energy up to 1 GeV. In these experiments the double cone Vavilov–Cherenkov radiation and some of its interesting variations were discovered [50–52]. In the studies of Cherenkov radiation in biaxial crystal of triglycine sulfate at CERN SPS lead beam [53] some interesting phenomena were found [54].

In studies at 100 A GeV gold beams at BNL we intend to look for so called "parametric Roentgen radiation" or "resonance radiation" [55]. This radiation could be generated in biaxial crystals with domain structure like Rochelle salt or triglycine sulfate. A special detector – Cherenkov photo camera (Fig. 7) will be used. In this photo camera the Cherenkov light is detected by 18 cm × 24 cm film. This camera was used in a number of previous experiments.

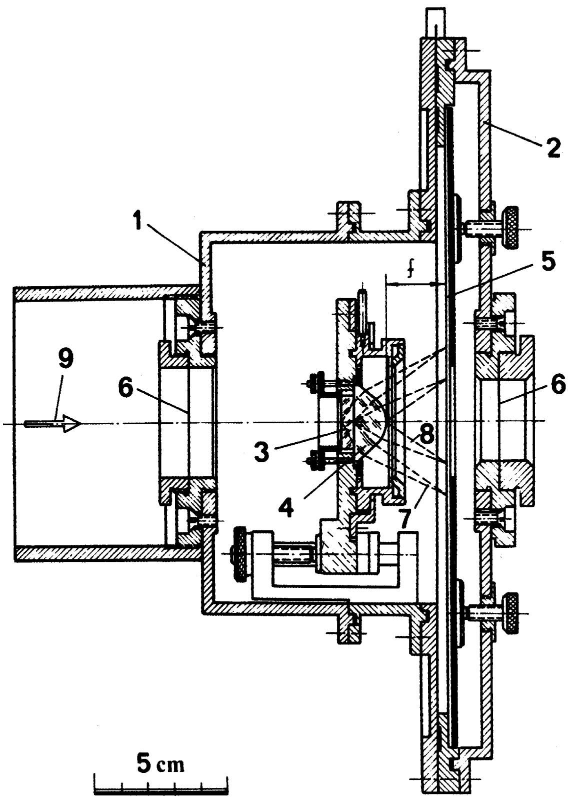


Fig. 7. Principal scheme of Cherenkov photo camera for the study of Cherenkov radiation in anisotropy media: 1 – light-proof body; 2 – film cassette; 3 – crystal; 4 – focusing lens with $n_D = 1.512$ and $f = 22.7$ mm; 5 – film (18 × 24 cm); 6 – thin entrance windows; 7 – radiation from the crystal; 8 – radiation from the lens; 9 – ion beam.

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