

THE PREWAVE ZONE EFFECTS IN BREMSSTRAHLUNG AND TRANSITION RADIATION BY RELATIVISTIC ELECTRON

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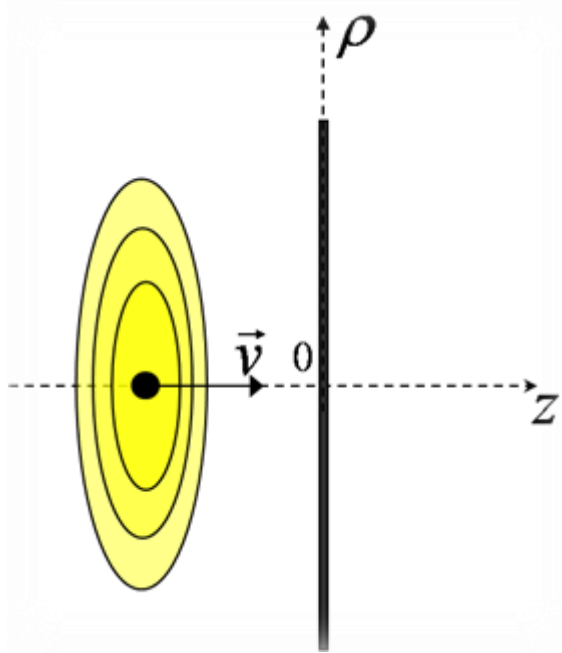
Belgorod State University, Belgorod, Russian Federation

- *J. Kharkiv National University* – 2010 – № 916 – iss. 3(47)
- *JETP Letters* – 2011 – v. 93
- *Il Nuovo Cimento C* – 2011 – v. 34

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- ❖ Structure of Transition radiation electromagnetic field
- ❖ The problem of measurement of Transition radiation and Bremsstrahlung characteristics
- ❖ Transition radiation by electron with nonequilibrium field (“half-bare” electron)

TRANSITION RADIATION BY ELECTRON WITH EQUILIBRIUM FIELD



Total field:

$$\varphi = \varphi^c + \varphi^f$$

Boundary condition:

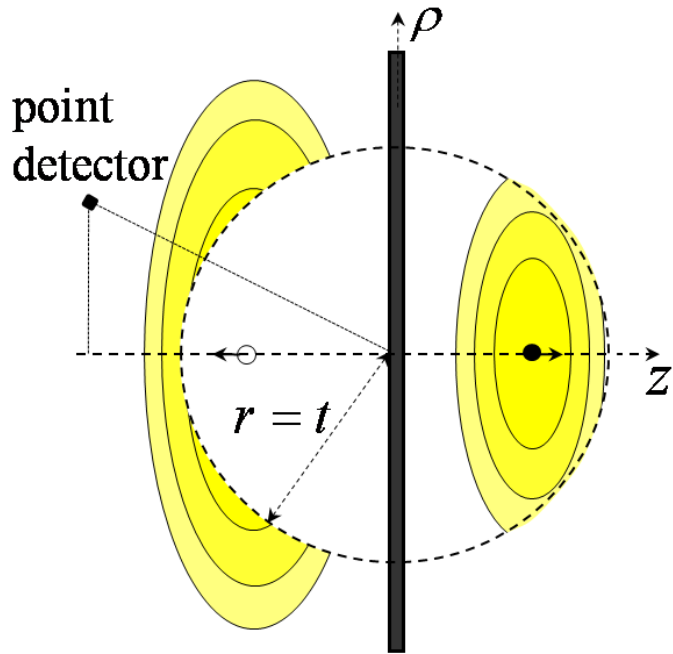
$$\vec{E}_\perp^c(\vec{\rho}, z=0, t) + \vec{E}_\perp^f(\vec{\rho}, z=0, t) = 0$$

Fourier integral for radiation field:

$$\varphi^f(\vec{r}, t) = -\frac{e}{\pi v} \int_{-\infty}^{\infty} d\omega \int_0^{\infty} dk_\perp k_\perp \frac{J_0(k_\perp \rho)}{k_\perp^2 + \omega^2 / v^2 \gamma^2} e^{i(z\sqrt{\omega^2 - k_\perp^2} - \omega t)}$$

$J_0(x)$ – Bessel function

STRUCTURE OF TR ELECTROMAGNETIC FIELD



Tomsk experiment: absence of currents on downstream surface
*G. Naumenko, A. Potylitsyn et al.,
 J. of Phys.: Conf. Ser. 236 (2010)*

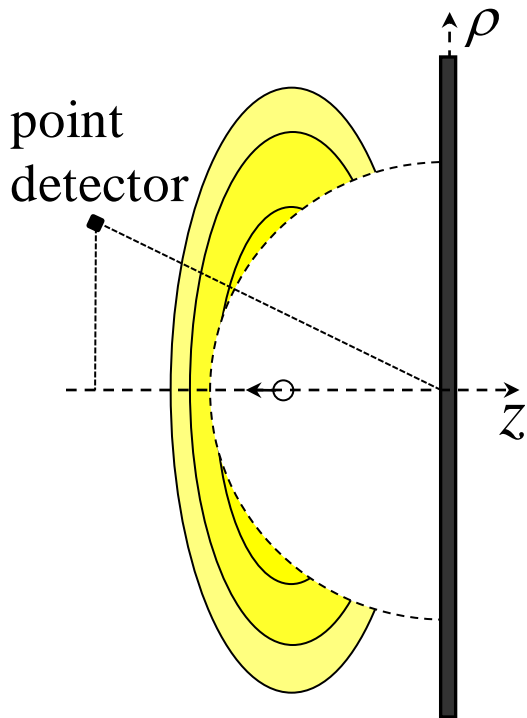
For $t > 0$:

$$\varphi(\vec{r}, t) = \left[\frac{e}{\sqrt{\rho^2 \gamma^{-2} + (z - vt)^2}} - \frac{e}{\sqrt{\rho^2 \gamma^{-2} + (z + vt)^2}} \right] [\theta(t - r)\theta(z) + \theta(r - t)\theta(-z)]$$

$$\vec{A}(\vec{r}, t) = \vec{v} \left[\frac{e}{\sqrt{\rho^2 \gamma^{-2} + (z - vt)^2}} + \frac{e}{\sqrt{\rho^2 \gamma^{-2} + (z + vt)^2}} \right] [\theta(t - r)\theta(z) + \theta(r - t)\theta(-z)]$$

It is not the same as in *B. Bolotovskiy, A. Serov // Phys. Usp., 2009*

THE PROBLEM OF TRANSITION RADIATION MEASUREMENT



On the sphere surface $r = t$:

$$\frac{d\mathcal{E}}{d\omega d\Omega} = \frac{e^2}{\pi^2} \frac{g^2}{(\gamma^{-2} + g^2)^2}$$

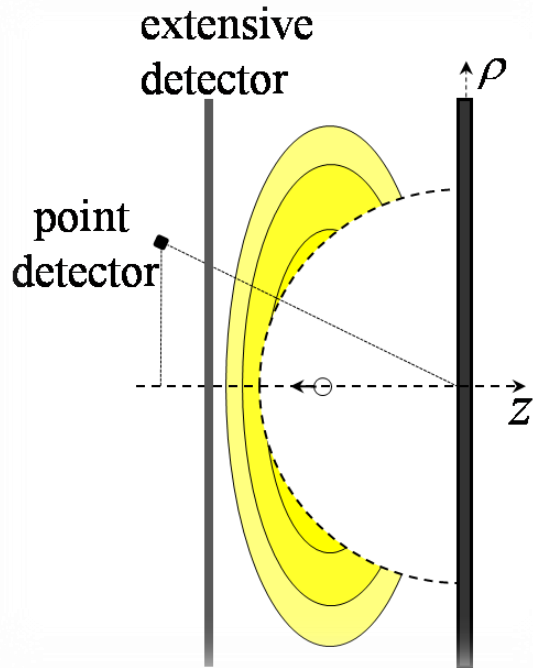
$$E = 50 \text{ Mev} \quad \lambda \approx 0.1 \text{ cm}$$

$$l_C \approx 2\gamma^2 \lambda \approx 20 \text{ m} \quad l_T \approx \gamma \lambda \approx 10 \text{ cm}$$

$z \ll 2\gamma^2 \lambda$ – pre-wave zone

$z \gg 2\gamma^2 \lambda$ – wave zone

THE PROBLEM OF TRANSITION RADIATION MEASUREMENT



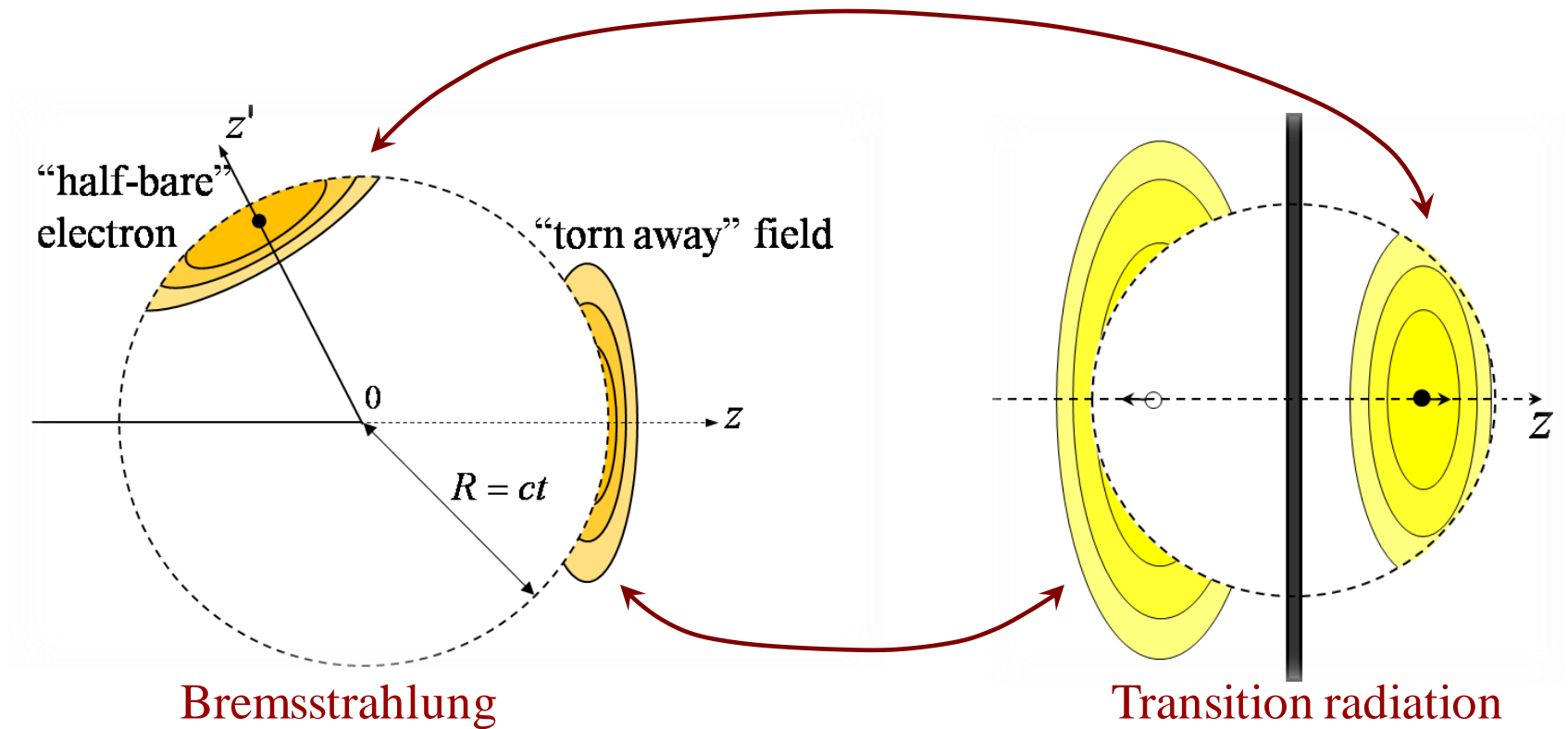
Verzilov V. // Phys. Lett. A. , 2000

Dobrovolsky S., Shul'ga N. // NIM B, 2003

The effect of large transversal radiation lengths in backward transition radiation:

The results of measurements substantially depend on the size and position of the detector

THE ANALOGY IN BREMSSTRAHLUNG



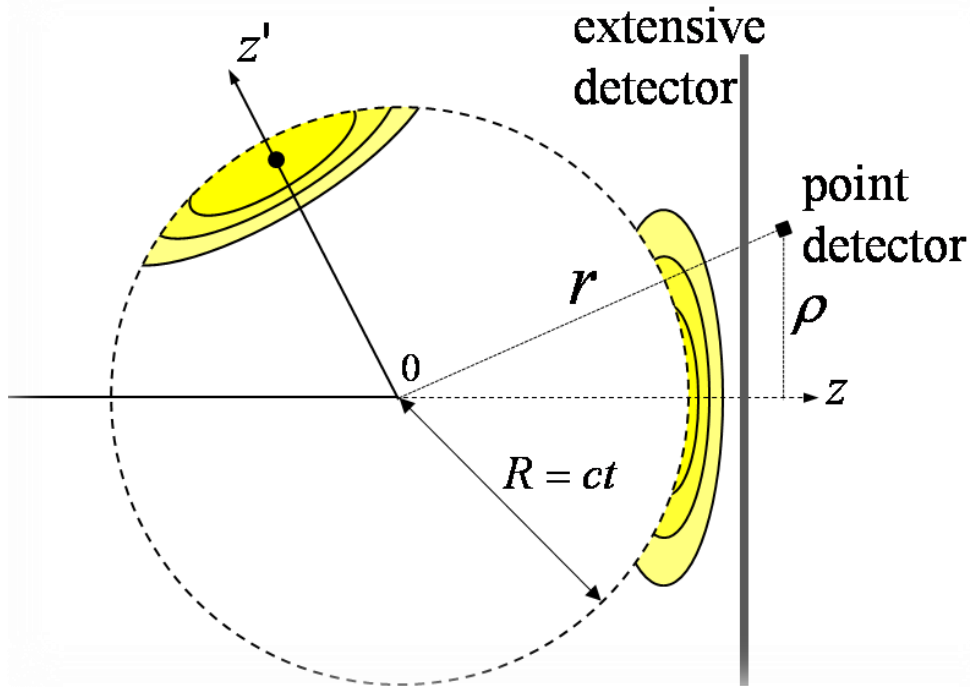
The total field for $t > 0$:

$$\varphi(\vec{r}, t) = \theta(r - t)\varphi_{\vec{v}}(\vec{r}, t) + \theta(t - r)\varphi_{\vec{v}'}(\vec{r}, t)$$

E.L. Feinberg // Sov. Phys. JETP, 1966

N. Shul'ga, V. Syshchenko, S. Shul'ga // Phys. Lett. A, 2009

THE ANALOGY IN BREMSSTRAHLUNG



Point detector $\Delta\rho \ll \gamma / \omega$:

$|z| \gg l_c$:

$$\frac{d\mathcal{E}}{d\omega d\Omega} = \frac{e^2}{\pi^2} \frac{\mathcal{G}^2}{(\gamma^{-2} + \mathcal{G}^2)^2}$$

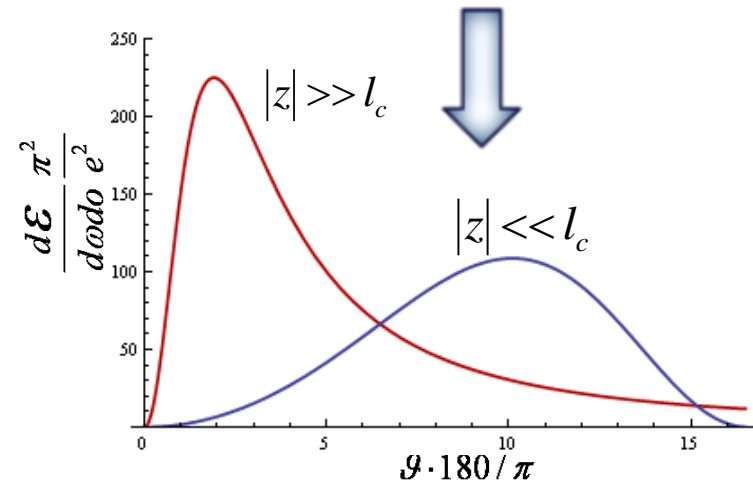
$|z| \ll l_c$:

$$\frac{d\mathcal{E}}{d\omega d\Omega} = \frac{4e^2}{\pi^2} \frac{1}{\mathcal{G}^2} \sin^2\left(\frac{\omega |z| \mathcal{G}^2}{4}\right)$$

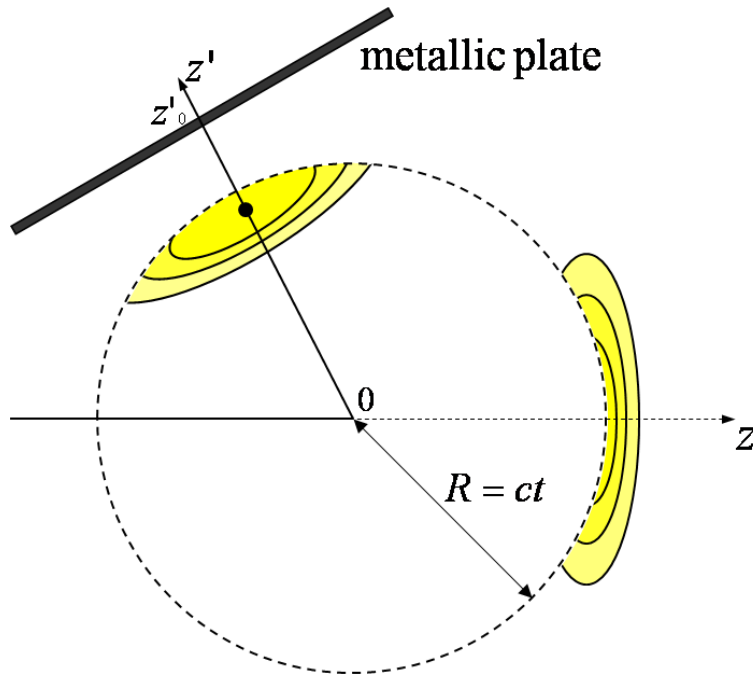
Extensive detector $\Delta\rho \gg \gamma / \omega$:

arbitrary z :

$$\frac{d\mathcal{E}}{d\omega d\Omega} = \frac{e^2}{\pi^2} \frac{\mathcal{G}^2}{(\gamma^{-2} + \mathcal{G}^2)^2}$$



TRANSITION RADIATION BY ELECTRON WITH NONEQUILIBRIUM FIELD



**Transition radiation by
“torn away” field :**

$$\frac{d\mathcal{E}}{d\omega do} = \frac{e^2}{\pi^2} \frac{\mathcal{G}^2}{(\gamma^{-2} + \mathcal{G}^2)^2}$$

does not depend on z_0

$$l_c \approx 2\gamma^2 / \omega$$

Transition radiation in wave zone by electron with nonequilibrium field :

$$\frac{d\mathcal{E}}{d\omega do} = \frac{e^2}{\pi^2} \frac{\mathcal{G}^2}{(\mathcal{G}^2 + \gamma^{-2})^2} 2 \left\{ 1 - \cos \left[\frac{\omega z'_0}{2} (\gamma^{-2} + \mathcal{G}^2) \right] \right\}$$

TRANSITION RADIATION BY ELECTRON WITH NONEQUILIBRIUM FIELD

Transition radiation in wave zone by electron with nonequilibrium field :

$$\frac{d\mathcal{E}}{d\omega d\phi} = \frac{e^2}{\pi^2} \frac{\mathcal{G}^2}{(\mathcal{G}^2 + \gamma^{-2})^2} 2 \left\{ 1 - \cos \left[\frac{\omega z'_0}{2} (\gamma^{-2} + \mathcal{G}^2) \right] \right\}$$

- suppression of radiation for $z'_0 \ll l_C$

- period of oscillations $\Lambda = \frac{4\pi}{\omega(\mathcal{G}^2 + \gamma^{-2})}$

- the oscillations can be observed for $z'_0 < \frac{2\pi}{\Delta\omega (\mathcal{G}^2 + \gamma^{-2})}$

$\Delta\omega$ – detector's resolution for frequency ω

COCONCLUSIONS

- Analogous electromagnetic field structure for TR and Bremsstrahlung
- Similar effects in TR and Bremsstrahlung
- Possibility of measurements in pre-wave zone
- Same results for point and extensive detectors in wave zone
- Substantial dependence of results on the detector's size in pre-wave zone
- Manifestation of electron's "half-bare" state by its transition radiation

THANK YOU!