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

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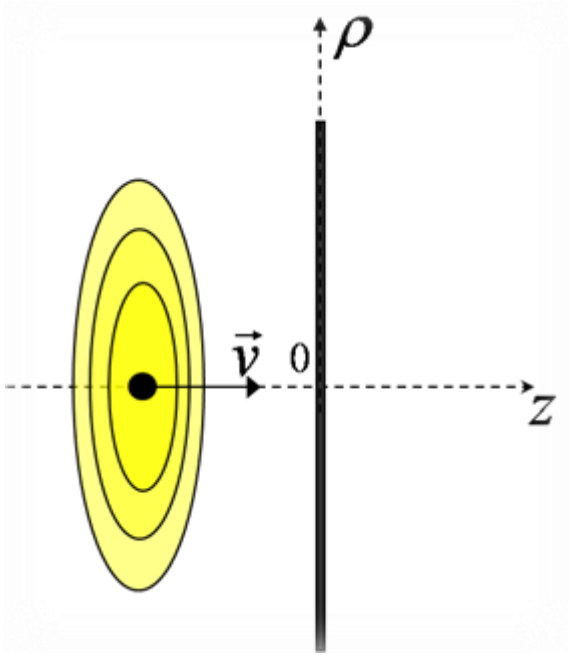
- Structure of Transition radiation electromagnetic field
- The problem of measurement of Transition radiation and Bremsstrahlung characteristics
- Transition radiation by electron with nonequilibrium field (“half-bare” electron)

TRANSITION RADIATION BY ELECTRON WITH EQUILIBRIUM FIELD



Total field:

$$\varphi = \varphi^C + \varphi^f$$

Boundary condition:

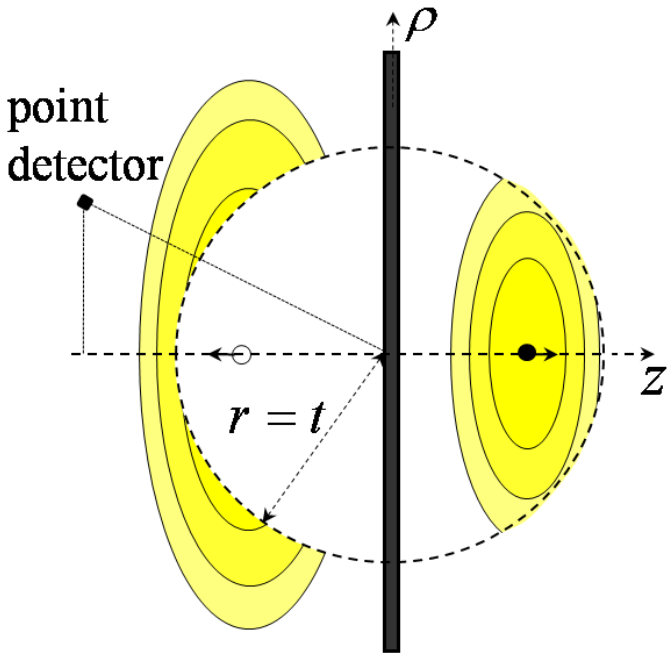
$$\vec{E}_\perp^{\,C}(\vec{\rho}, z=0, t) + \vec{E}_\perp^{\,f}(\vec{\rho}, z=0, t) = 0$$

Fourier integral for radiation field:

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

$J_0(x)$ – 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)

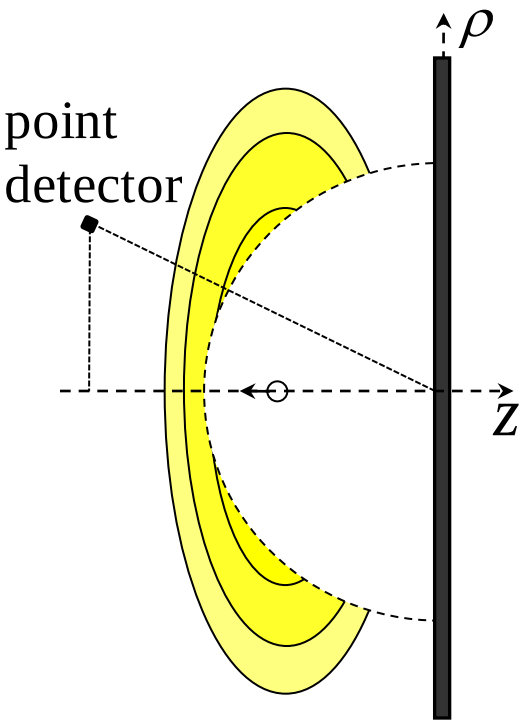
For $t > 0$ **:**

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

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

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

THE PROBLEM OF TRANSITION RADIATION MEASUREMENT



On the sphere surface $r = t$:

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

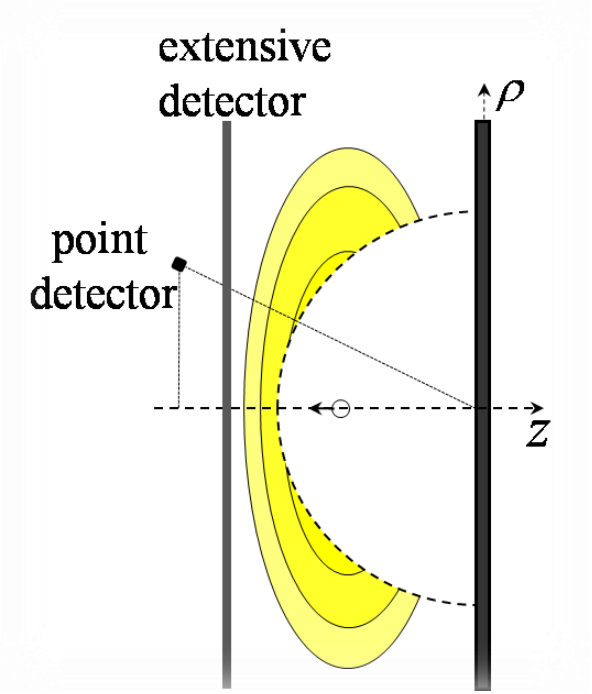
$$E = 50 Mev \qquad \lambda \approx 0.1 cm$$

$$l_C \approx 2\gamma^2 \lambda \approx 20 m \qquad l_T \approx \gamma\lambda \approx 10 cm$$

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

$z >> 2\gamma^2\lambda$ – wave zone

THE PROBLEM OF TRANSITION RADIATION MEASUREMENT

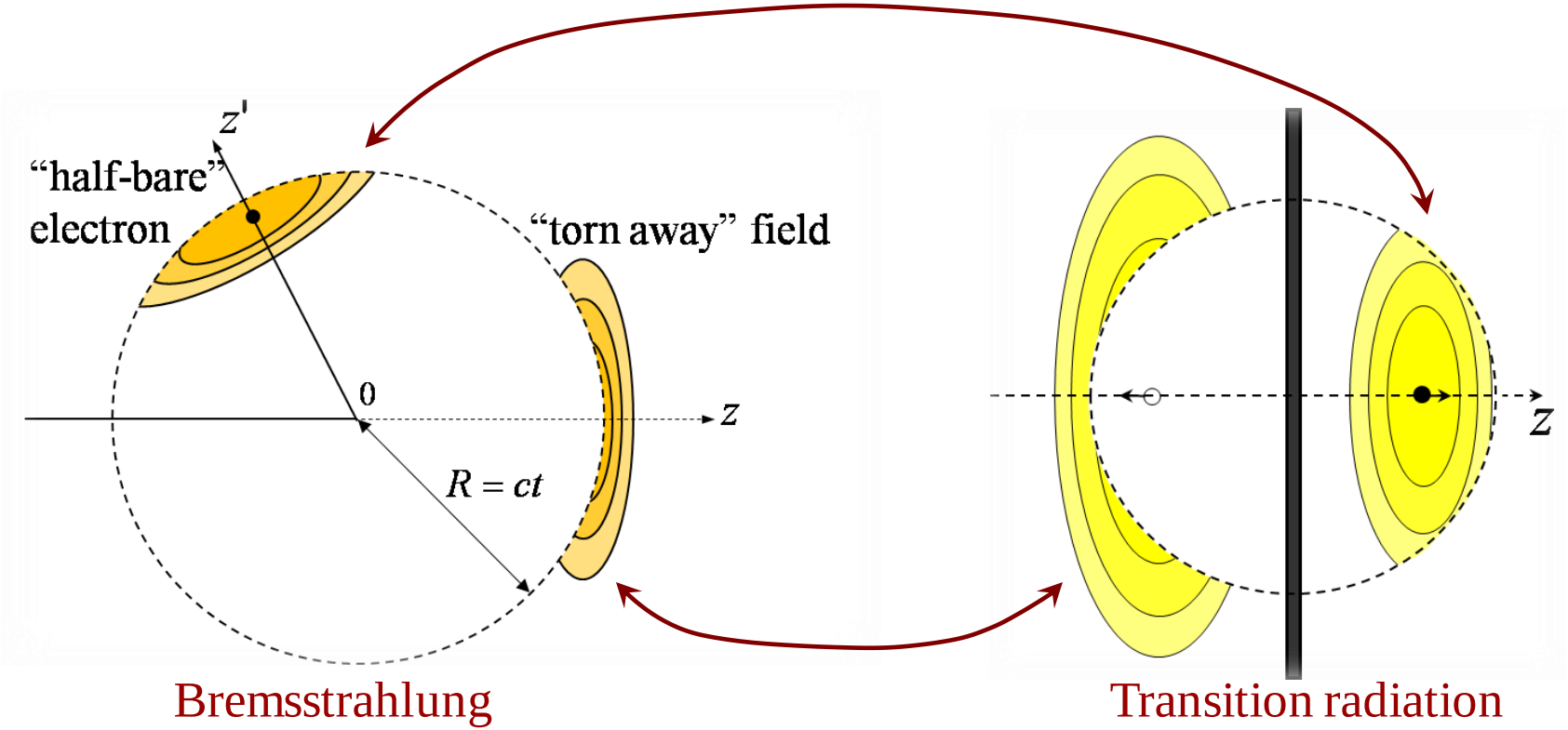


Verzilov V. // Phys. Lett. A. , 2000
Dobrovolsky S., Shul'ga N. // NIM B, 2003

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



Bremsstrahlung

Transition radiation

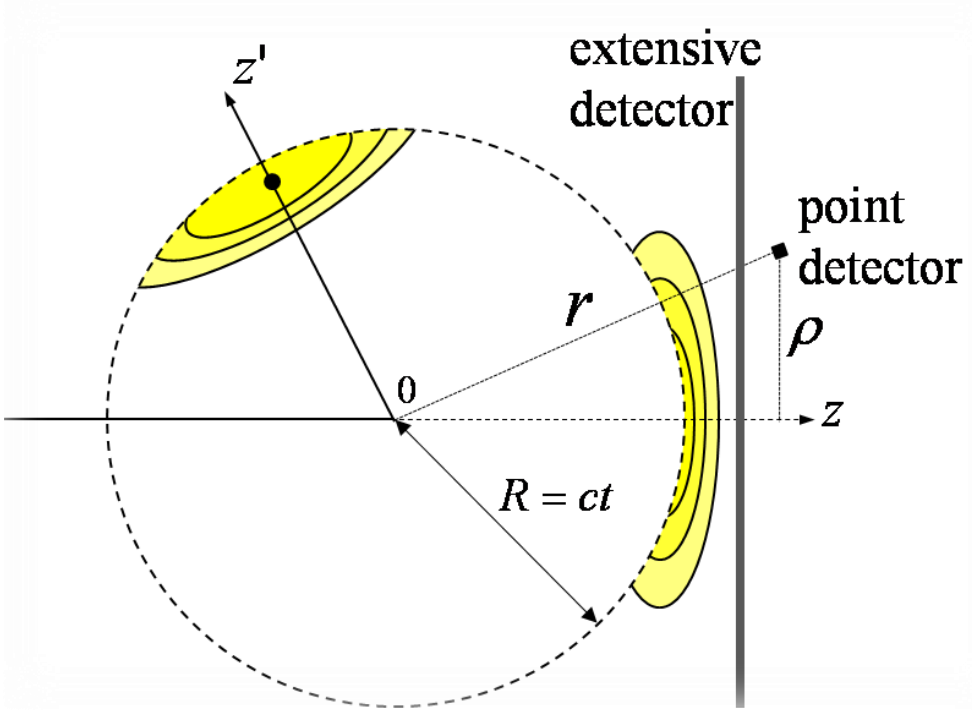
The total field for $t > 0$:

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

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 $\Delta\rho << \gamma/\omega$ **:**

$|z| >> l_c$:

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

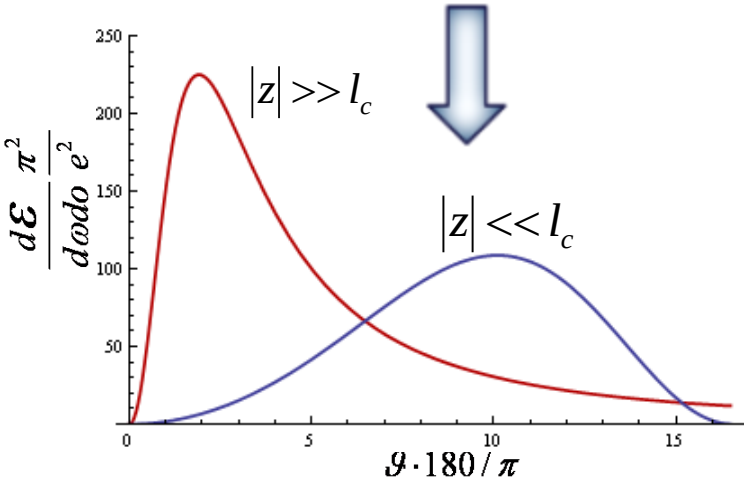
$|z| << l_c$:

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

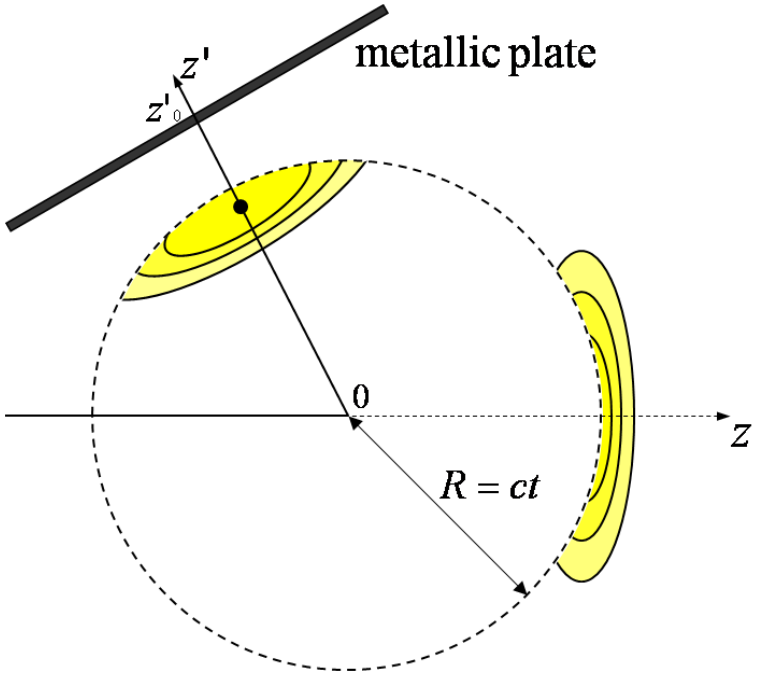
Extensive detector $\Delta\rho >> \gamma/\omega$ **:**

arbitrary z :

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



TRANSITION RADIATION BY ELECTRON WITH NONEQUILIBRIUM FIELD



Transition radiation by "torn away" field :

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

does not depend on z_0

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

Transition radiation in wave zone by electron with nonequilibrium field :

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

TRANSITION RADIATION BY ELECTRON WITH NONEQUILIBRIUM FIELD

Transition radiation in wave zone by electron with nonequilibrium field :

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

- suppression of radiation for $z'_0 << l_C$
- period of oscillations $\Lambda = \dfrac{4\pi}{\omega(\vartheta^2+\gamma^{-2})}$
- the oscillations can be observed for $z'_0 < \dfrac{2\pi}{\Delta\omega\ (\vartheta^2+\gamma^{-2})}$

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

COCNCLUSIONS

- 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 it's transition radiation

THANK YOU!