"Channeling 2010"

Investigation of the electron electromagnetic field in a shadow area

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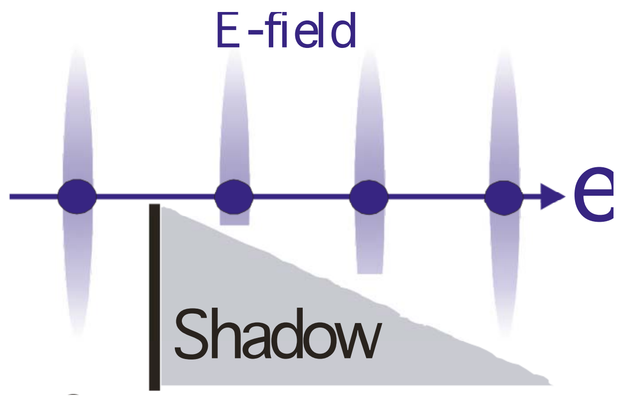
About the problem

Shadowing effect

(half-naked electron,
semi-bare electron,
radiation formation zone)

E.L. Feĭnberg Sov. Phys. Uspekhi, 22 (1979) 479-479.
X. Artru, NIM B 266 (2008) 3725.
N.F. Shul'ga and V.V. Syshchenko. Journal Physics of Atomic Nuclei, 63, 11, (2000), 2018
B. M. BolotovskiI. Preprints of Lebedev Institute of Physics, Russian Academy of Sciences,Vol 140 p. 95



Absorber or conductive screen

Viewpoints:

Surface current viewpoint

(Interference of the forward DR (TR), emitted by induced surface current, with electron field)

In paper
"*G Naumenko, A. Potylitsyn et. al. Journal of Physics: Conference Series 236 (2010) 012024*"
was shown that
no surface current is induced on a downstream surface of a screen.

Surface current viewpoint is not applicable for this problem

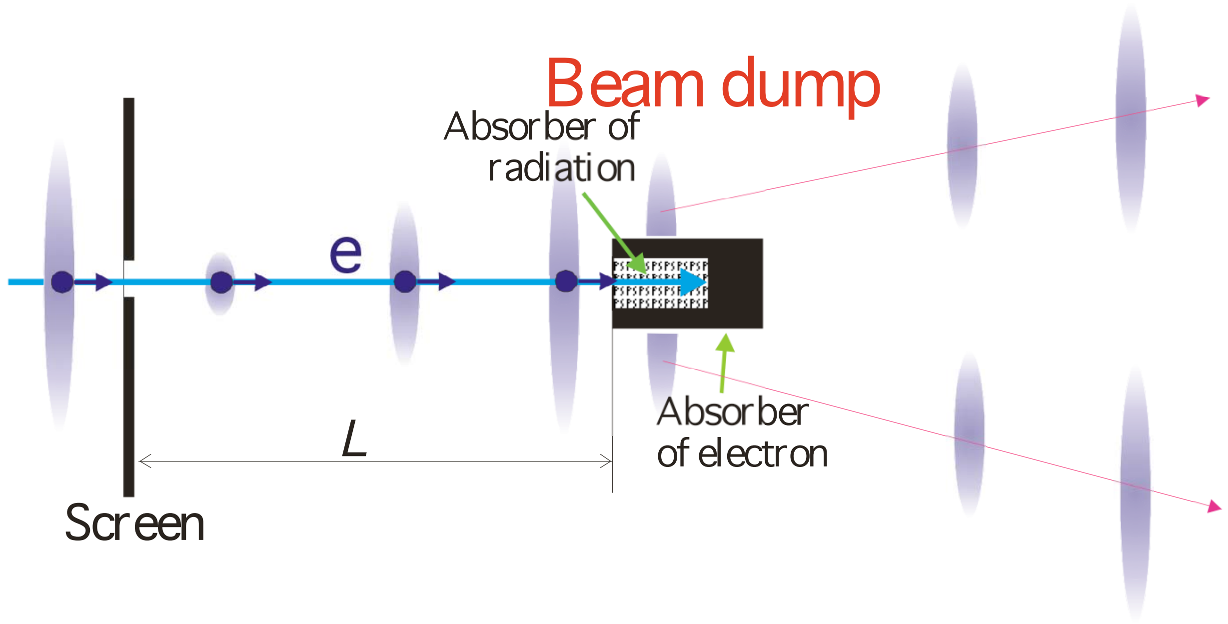
Pseudo-photon (equivalent photon / virtual photon) viewpoint

- **Electron field must be reflected from a conductive screen,**
- **It doesn't penetrate through thick conductive screen or absorber,**
- **It doesn't induce a surface current on the downstream surface of a screen**

Therefore we may expect the semibare electron just downstream to the screen

Can we observe this effect experimentally ?

Possible scheme of experiment



We should use a model for electromagnetic field evolution from screen to beam dump without acceleration (starting and stopping of electron).

Theory

$\vec{\beta}\,' = 0$

Field of moving electron:

$$\vec{E} = \frac{e}{\left(R-\vec{\beta}\vec{R}\right)^3}\left\{\left(1-\beta^2\right)\left(\vec{R}-\vec{\beta}R\right)+\vec{R}\times\left(\left(\vec{R}-\vec{\beta}R\right)\times\vec{\beta}\,'\right)\right\}$$, here C=1

In Fourier presentation
in terms of the retarded time:

$$\vec{E}_\omega = \int_0^{L/\beta}\frac{e\cdot\left(1-\beta^2\right)\cdot\left(\vec{R}-\vec{\beta}R\right)}{\left(R-\vec{\beta}\vec{R}\right)^3}\cdot e^{i\omega(t'+R)}\frac{\partial t}{\partial t'}dt'$$

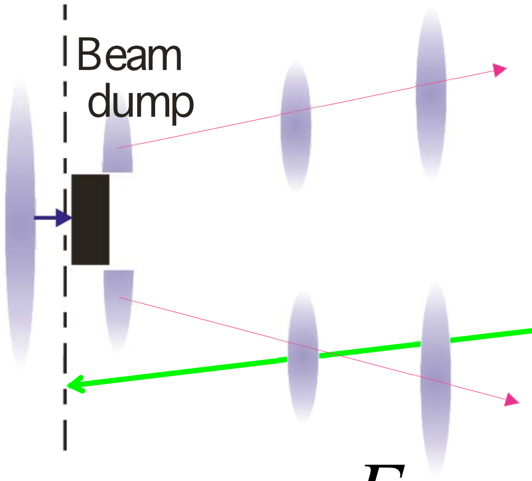
t is the retarded time

$$t = t' + R\left(t'\right)$$

Transversal component in case of axial symmetry:

$$\vec{E}_\omega^{\perp} = \int_0^{L/\beta}\frac{e\cdot\left(1-\beta^2\right)\cdot r}{\left(R-\beta R_\beta\right)^3}\cdot e^{i\omega\left(t'+R\right)}\frac{\partial t}{\partial t'}dt'$$

r is transversal coordinate of the observation point



For a field evolution from beam dump to infinity we use Kirhoff integral in plane of beam dump.

Observation angle

$$E_\theta = \omega \int_{r_{bd}}^{\infty} E_\omega^\perp \cdot J_1\left(-\omega \cdot r \cdot \theta\right) r \; dr$$

Beam dump radius

Bessel function

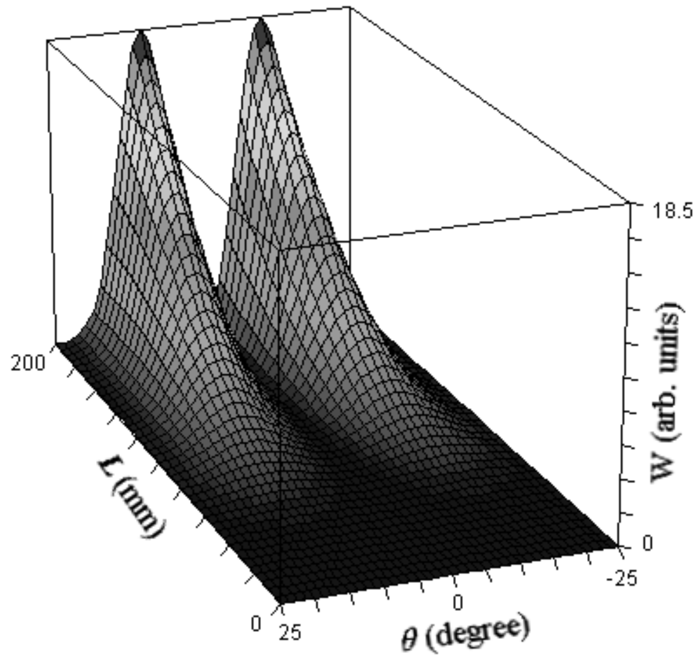
For experimental conditions:

$\gamma = 12$

$\lambda = 10mm$

r_{bd}=20mm

$\left|E_\theta\right|^2$

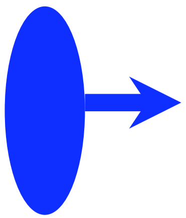


Experiment

Tomsk microtron Electron Beam

Beam parameters

bunch



$N \approx 10^8$

$\sigma_l \approx 1.6$ *mm*

$\lambda > 9mm$

Coherent radiation

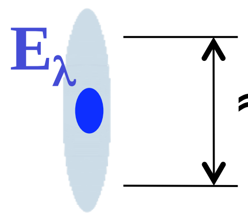
$$\left|\vec{E}\right|^2 = N^2 \left| f\left(\frac{\lambda}{\sigma}\right)\right|^2 \cdot \left|\vec{E}_e\right|^2$$

J. Nodvick, … // Phys.Rev. 96 - 1 (1954) P. 180.

Formation length

$$\frac{\gamma^2\lambda}{4} \approx \frac{12^2 \cdot 11\ mm}{4} = 0.4\ m$$

Electron field size



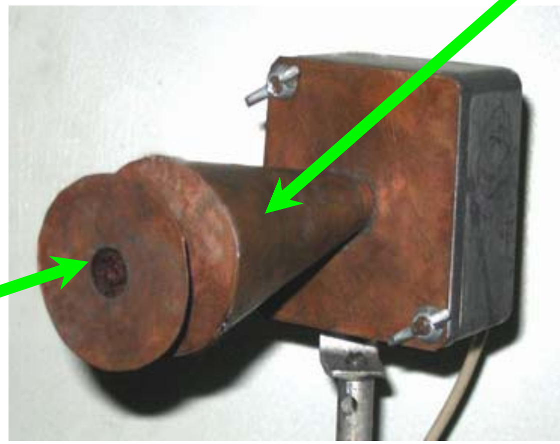
$\approx 2\gamma\lambda$

$$\gamma\lambda \approx 12 \cdot 11\ mm = 130\ mm$$

Detector parameters :

The room temperature detector DP20M Tomsk (Russia) production.

Horn



Broad bend detector

Beyond-cutoff waveguide
λ_{cut}=17 mm

Detector efficiency in the wavelength region λ=3~16 mm is certificated as a constant with accuracy ± 15%

$$\lambda = 9 \sim 17\ mm$$

Coherency

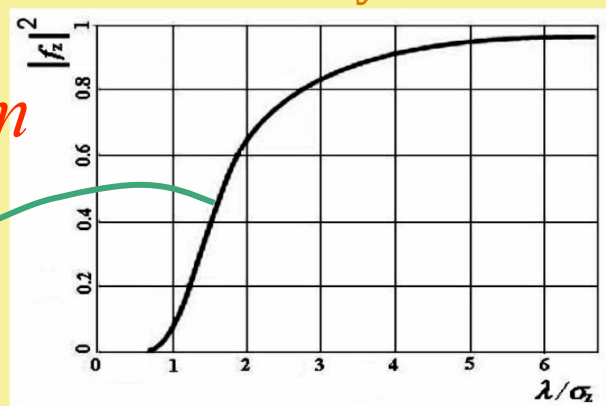
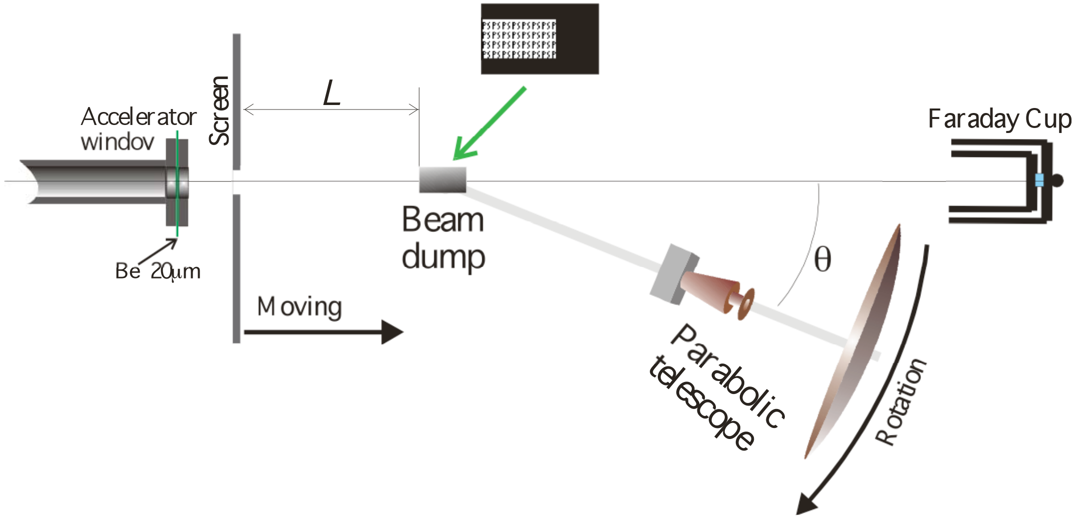
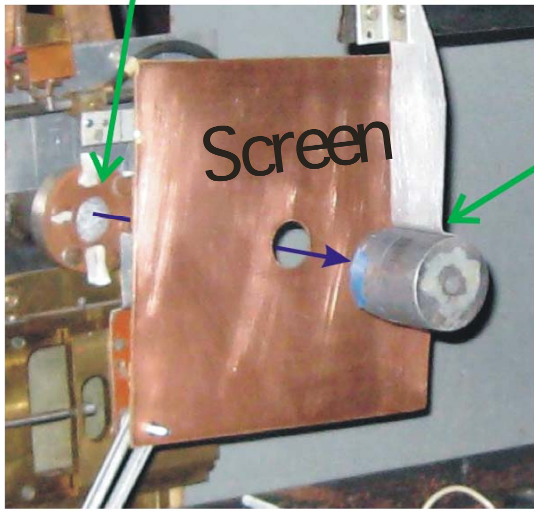


Fig.4 Dependence of the squared form-factor module on the radiation wavelength for the gaussian longitudinal distribution of electrons in a bunch.

Wavelength range: = 3 ~ 16 mm,
sensitivity = 0.3 V/mWatt

Scheme of experiment





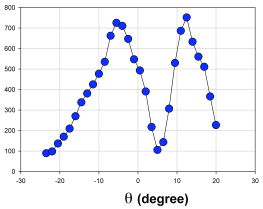
Parabolic telescope was used for angular distribution measurement to exclude the "pre-wave" zone effect contribution.

(*B.N. Kalinin, G.A. Naumenko, A.P. Potylitsyn et al, JETP Letters, 84, 3, (2006), p. 110.*)

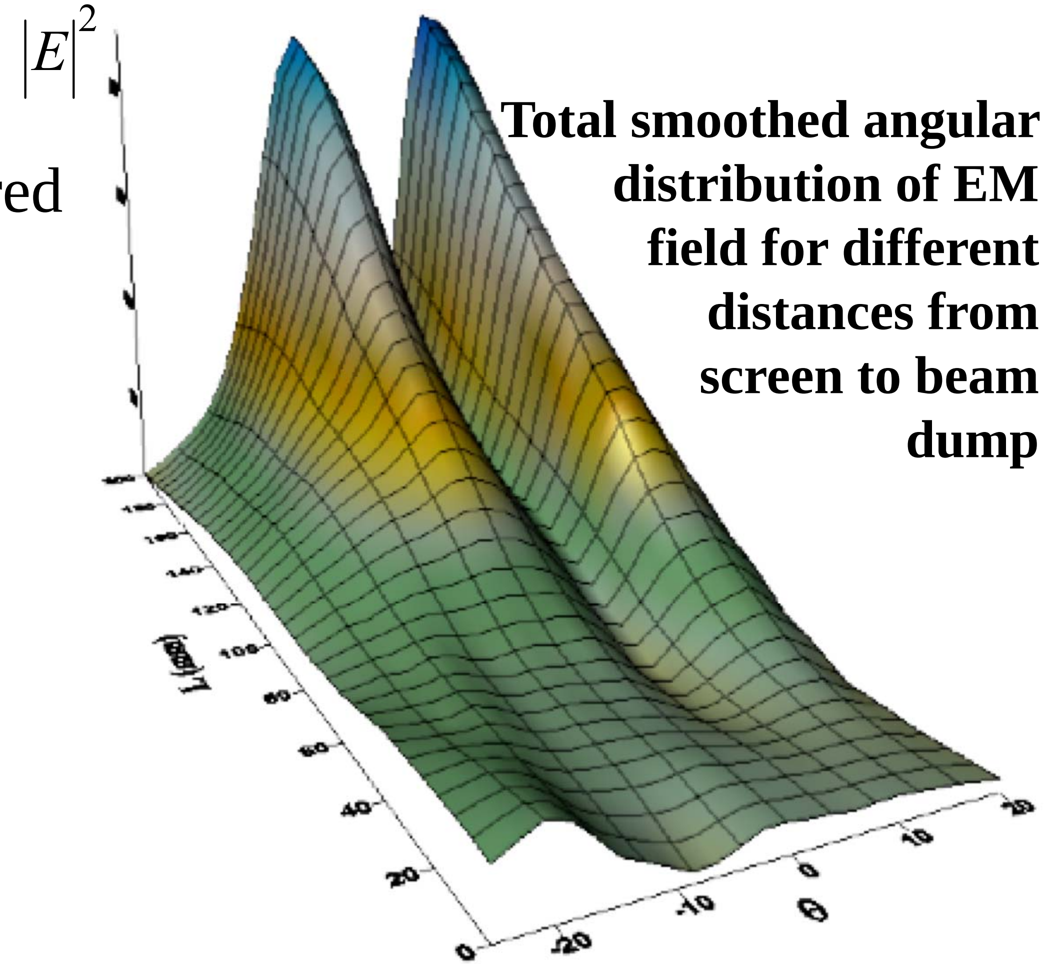
Measurements

Absorbed screen

The dependence was measured with the step $\Delta L = 20mm$



Typical measured angular distribution



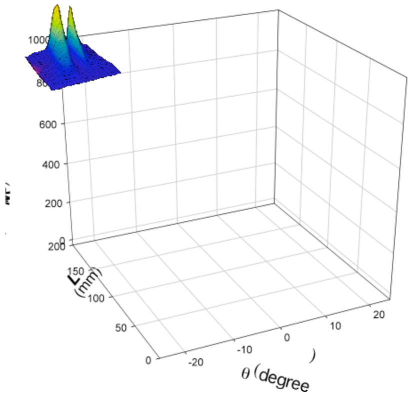
Total smoothed angular distribution of EM field for different distances from screen to beam dump

We see the recovery of electron field when the distance between screen and beam dump increase.

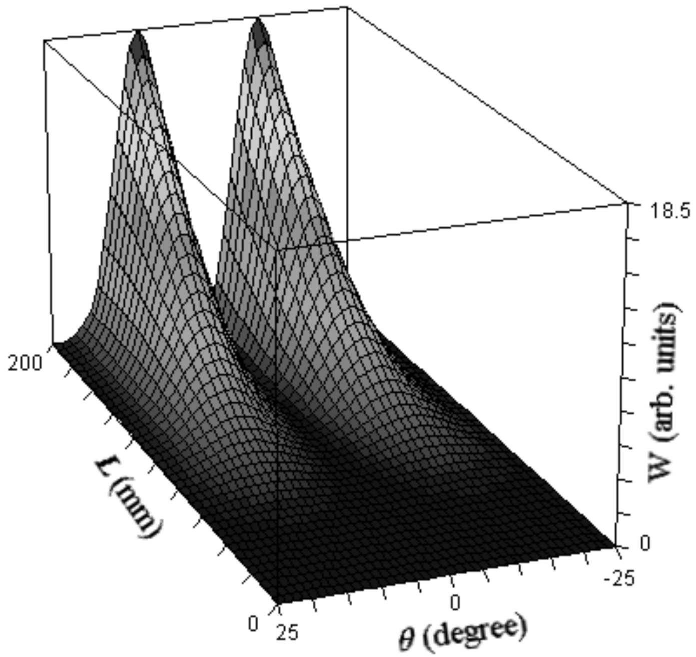
Conductive screen

Total experimental no smoothed dependence

Angular distribution of EM field in far field zone for different distance from screen to beam dump



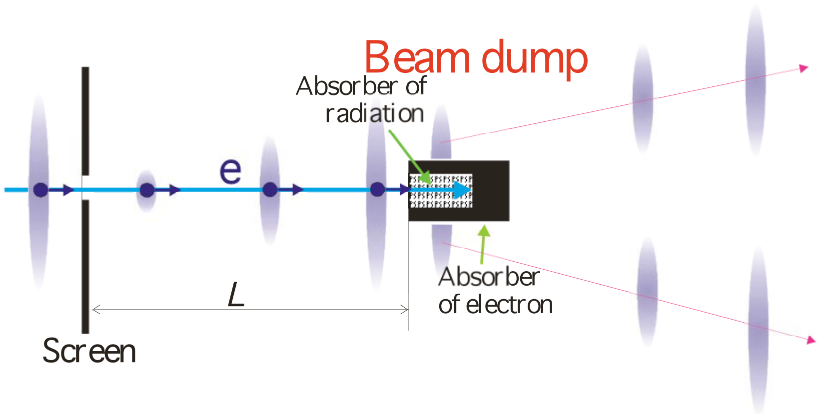
Let's remind you the theoretical dependence



Step $\Delta L = 10mm$

You can see that these dependences are very close

Resume



1. Both the absence of a surface current on a downstream conductive screen surface and the similarity of dependences from absorbed and conductive screens allows us to be ensure that we observe the semi-bare electrons just downstream to the screen.

2. The further evolution is the recovery of the Coulomb field of semi-bare electron to the state of usual electron.

3. Semi-bare electron properties were investigated experimentally in macroscopic mode

Thank you for your attention