THE ACTUAL PROBLEMS OF MICROWORLD PHYSICS

# INFLUENCE OF MULTIPLE SCATTERING ON ELECTROMAGNETIC RADIATION PRODUCED BY RELATIVISTIC ELECTRON BEAMS

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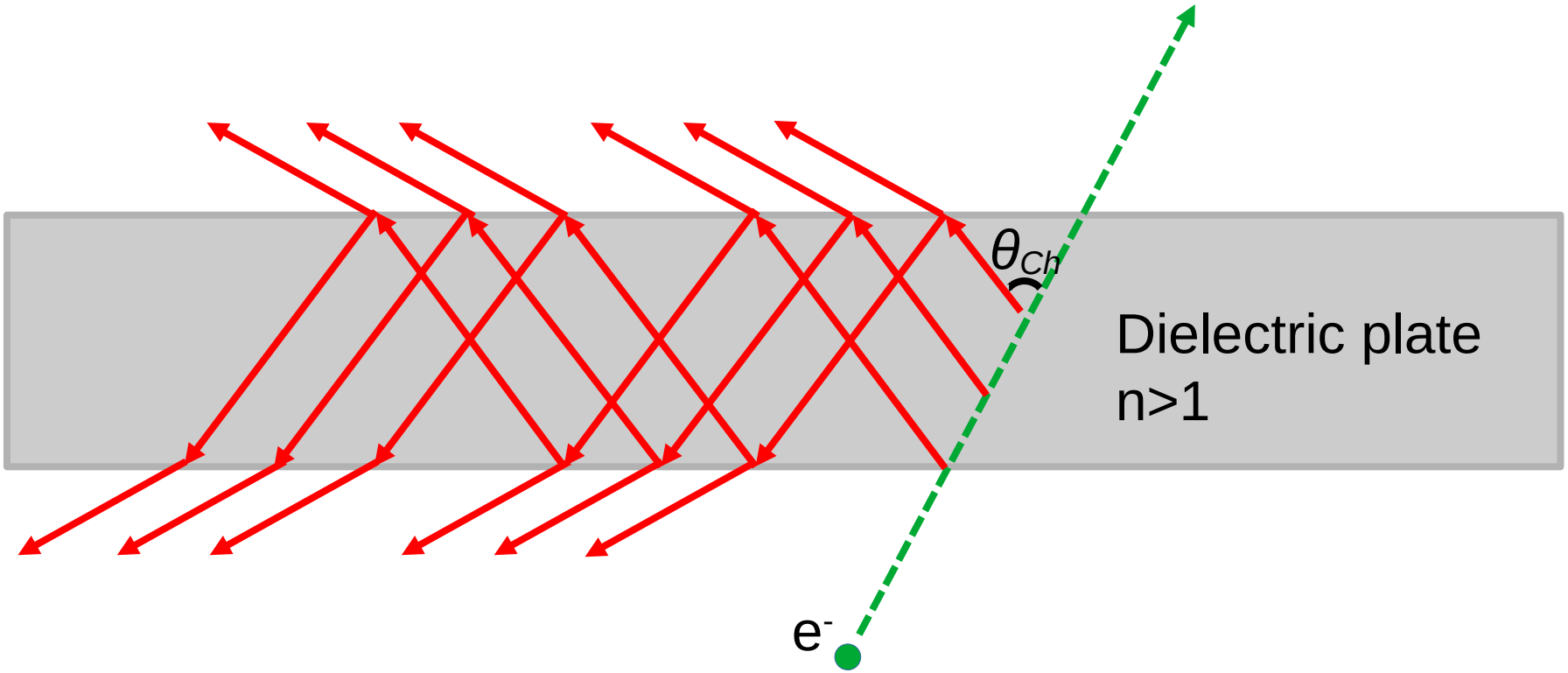
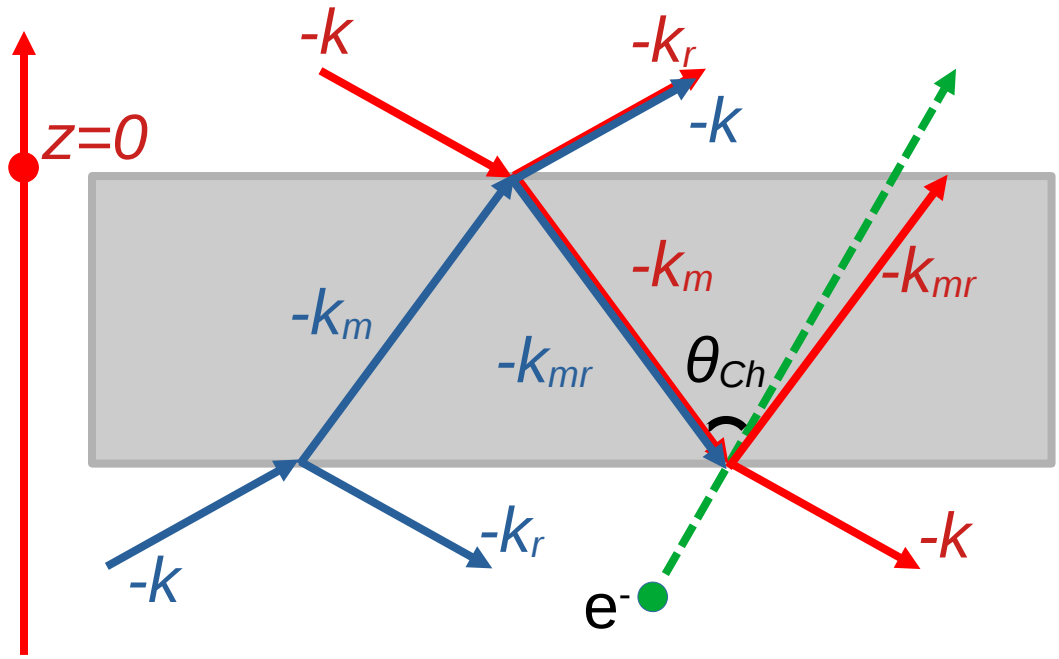
# Cherenkov radiation




Cherenkov P.A. DAN. 21. 323. 1938; Phys. Rev. 52. 378. 1937.
Vavilov S.I.  DAN 2 (8), 457 (1934)
Tamm I.E., Frank I.M. DAN. 14. 107. 1937.
Pafomov V.E., ZhETF, 33, 1074. 1957.

# Spectral-angular distribution

$$W_{s\vec{n}\omega} = \frac{e^2\omega^2}{4\pi^2 c^3} \iint_{T_1}^{T_2} \left(\vec{v}(t_1)\vec{E}^{(+)s}_{-\vec{k}}(\vec{r}(t_1),\omega)\right)\left(\vec{v}(t_2)\vec{E}^{(+)s*}_{-\vec{k}}(\vec{r}(t_2),\omega)\right) e^{i\omega(t_1-t_2)} dt_1 dt_2$$




$$\vec{E}^{(+)s}_{-\vec{k}} = \left(\vec{e}_{-\vec{k}} e^{-i\vec{k}\vec{r}} + \vec{e}_{-\vec{k}_r} B_0 e^{-i\vec{k}_r\vec{r}}\right)\Theta(z)$$
$$+ \left(\vec{e}_{-\vec{k}_m} A_1 e^{-i\vec{k}_m\vec{r}} + \vec{e}_{-\vec{k}_{mr}} B_1 e^{-i\vec{k}_{mr}\vec{r}}\right)\Theta(-z)\Theta(z+L)$$
$$+ \vec{e}_{-\vec{k}} A_2 e^{-i\vec{k}\vec{r}}\Theta(-z-L)$$

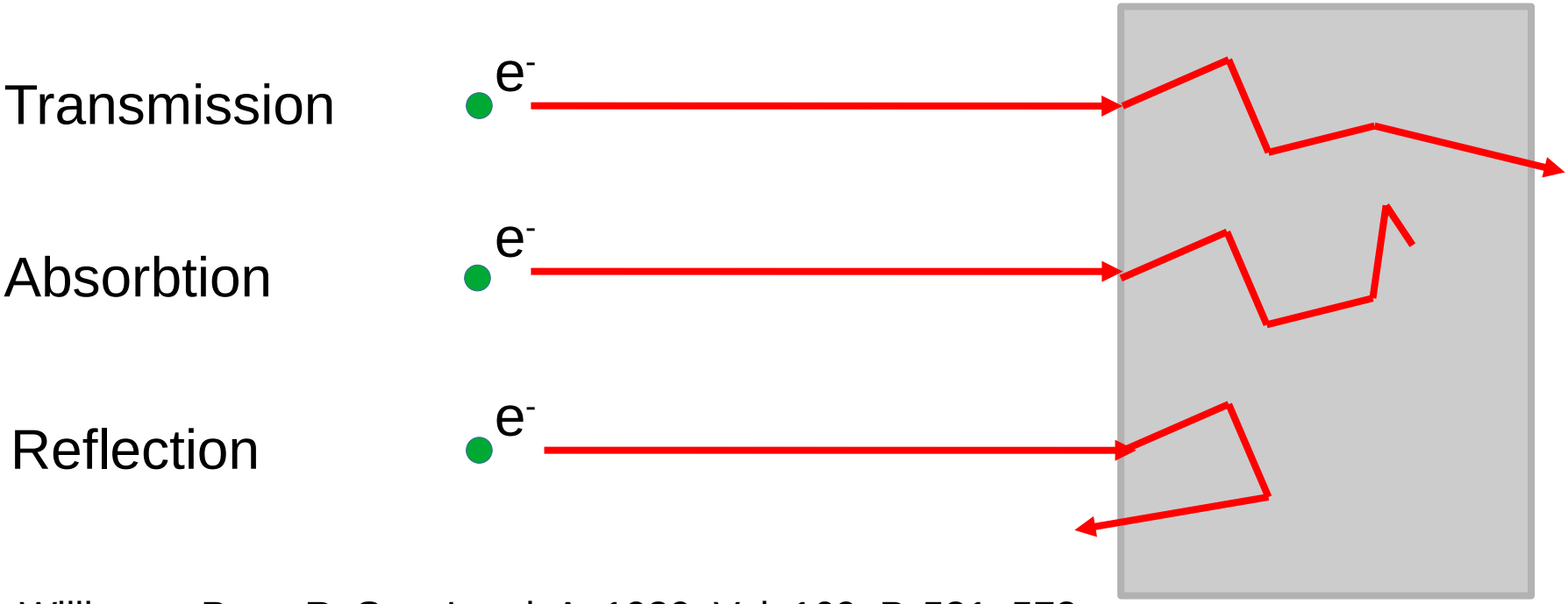
z=0

$$\omega - \vec{k}_m\vec{v} = 0$$

$$\omega - \vec{k}_{mr}\vec{v} = 0$$

Baryshevsky V.G. ZhETF. 1974. Vol. 67. P. 1651; Channeling, radiation and reactions in crystals at high energies, Minsk, 1982.

# Multiple scattering




E.J. Williams, Proc. R. Soc. Lond. A. 1939. Vol. 169, P. 531–572
E. Fermi, 1940 (see B. Rossi and K. Greisen, Rev. Mod. Phys. 1941. Vol. 13. P. 240.)
M.L. Ter-Mikaelian, High-energy electromagnetic processes in condensed media, Spronger, 1972.
***S. Gouldsmit and J.L. Saunderson, Phys. Rev., 1940. Vol. 57, P. 244–29.***
G. Moliere, Z. Naturforsch. Ba, 78 (1948); H.A. Bethe, Phys. Rev. 1953. Vol. 89. P. 1256–1266.
***S.M. Seltzer, Appl. Radiat. Isot. 1991. Vol. 42, No. 10. P. 917–941, 1991..***

# Ionization and radiation losses

**Ionization losses**

N. Bohr, Phil. Mag. 1913. Vol. 25., P. 10--31.
H. Bethe, Zeits. f. Physik, 1932, 76, 293.
F. Bloch, Ann. d Physik 16, 285 (1933).
F. Rohrlich and B.C. Carlson, Phys. Rev., 1954. Vol. 93., P. 38.

**Fluctuations**

L. Landau, J. Phys. USSR 8 (1944) 201.
O. Blunck, S. Leisengang, Zeits. f. Physik, 1950. Bd. 128., S. 500--505.
P.V. Vavilov, Sov. Phy. JETP, 1957. Vol. 5. No. 4, P. 749.

**Density effect**

E. Fermi, Phys. Rev. 1940. Vol. 57. P. 485.
R.M. Sternheimer, Phys. Rev., 1952. Vol. 88., P. 851--859.
R.M. Sternheimer, M.J. Berger, S.M. Seltzer,Atomic Data and Nuclear Tables 30 (1984).

**Radiation losses**

H. Bethe and W. Heitler, Proc. Roy. Soc. (London) A146 (1934) 83.
R.H. Pratt et al.,Atomic Data and Nuclear Data Tables 20 (1977).

# Simplification of Goudsmit-Sanderson theory

Longitudinal velocity

Segment length

$$v < \cos\theta >= v \exp(-n\sigma_1 s)$$

Particle velocity

Transport cross sections

Transverse velocity

$$v^2(1- < \cos^2\theta >) = v^2\left(1 - \frac{1 + 2\exp(-n\sigma_2 s)}{3}\right)$$

Multiple scattering angle

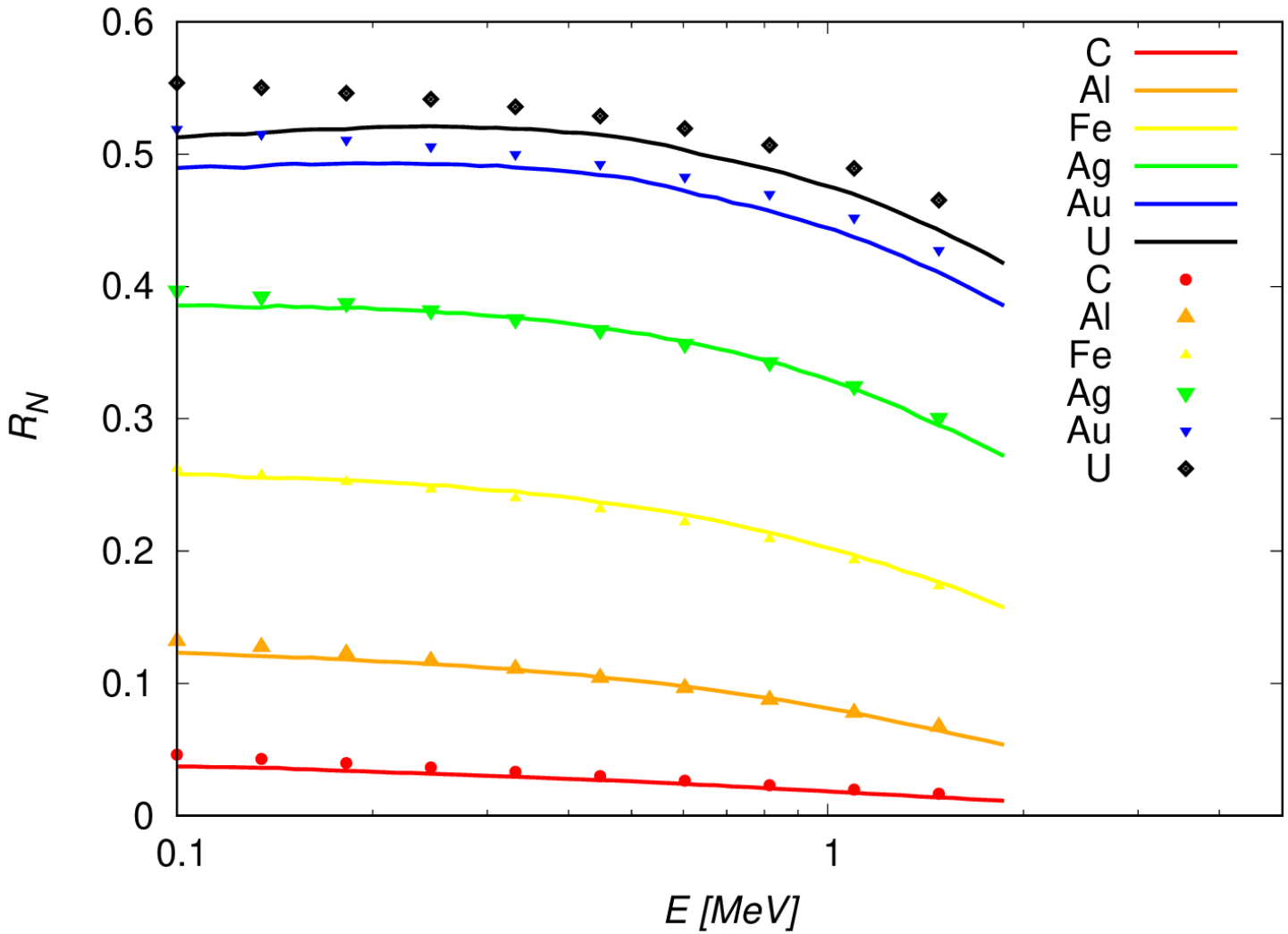
The number of atoms


H.W. Lewis, Phys. Rev. 1950. Vol. 78. P. 526.

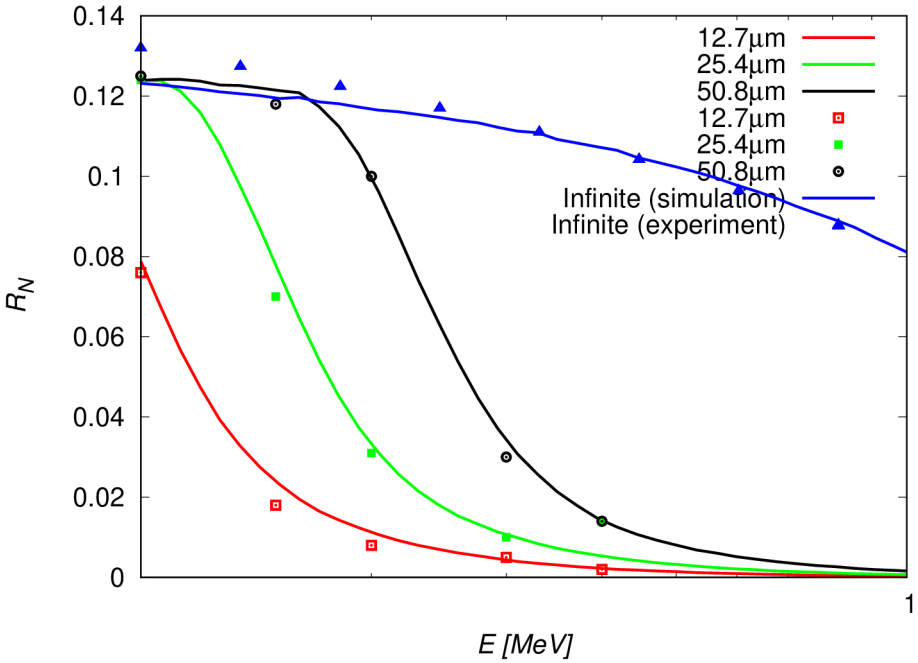
J.M. Fernandez-Varea, R. Mayol, J. Baro, and F. Salvat, Nucl. Instrum. Methods in Phys. Res. B73 (1993) 447–473.

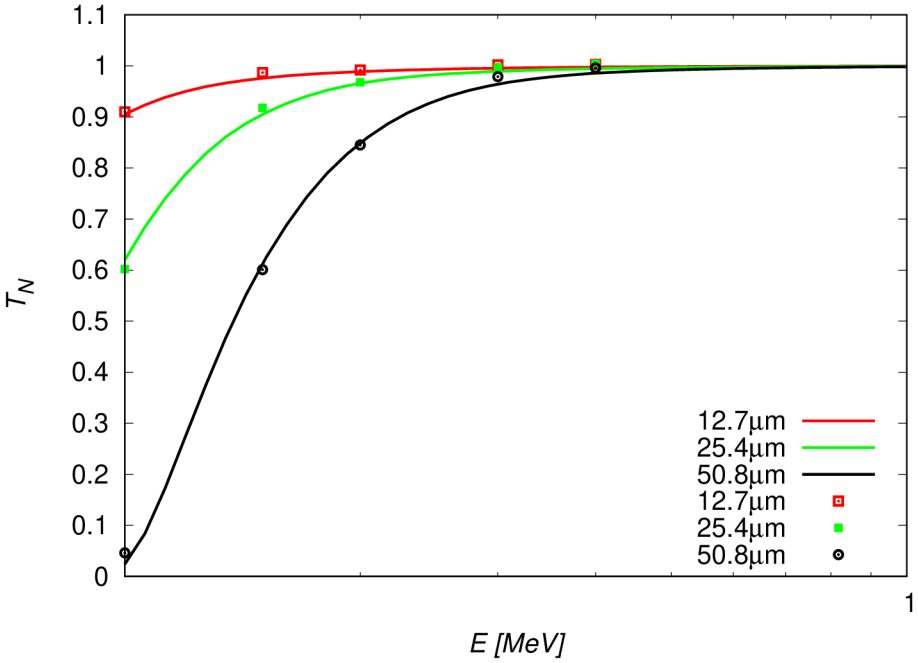
R. Mayol, F. Salvat, Atomic Data and Nuclear Data Tables 65 (1997).

# Electron reflection



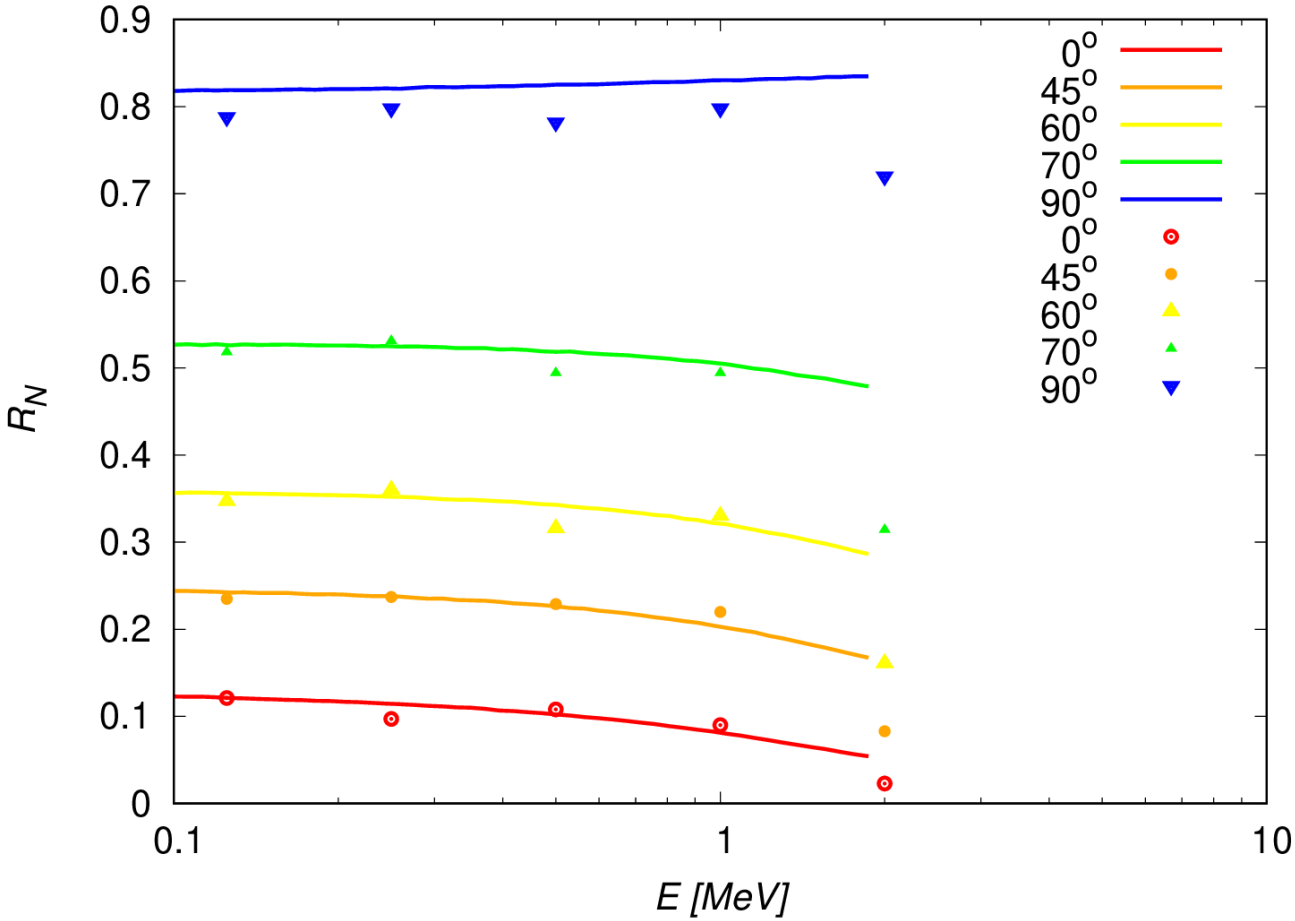
# Thin targets: aluminum



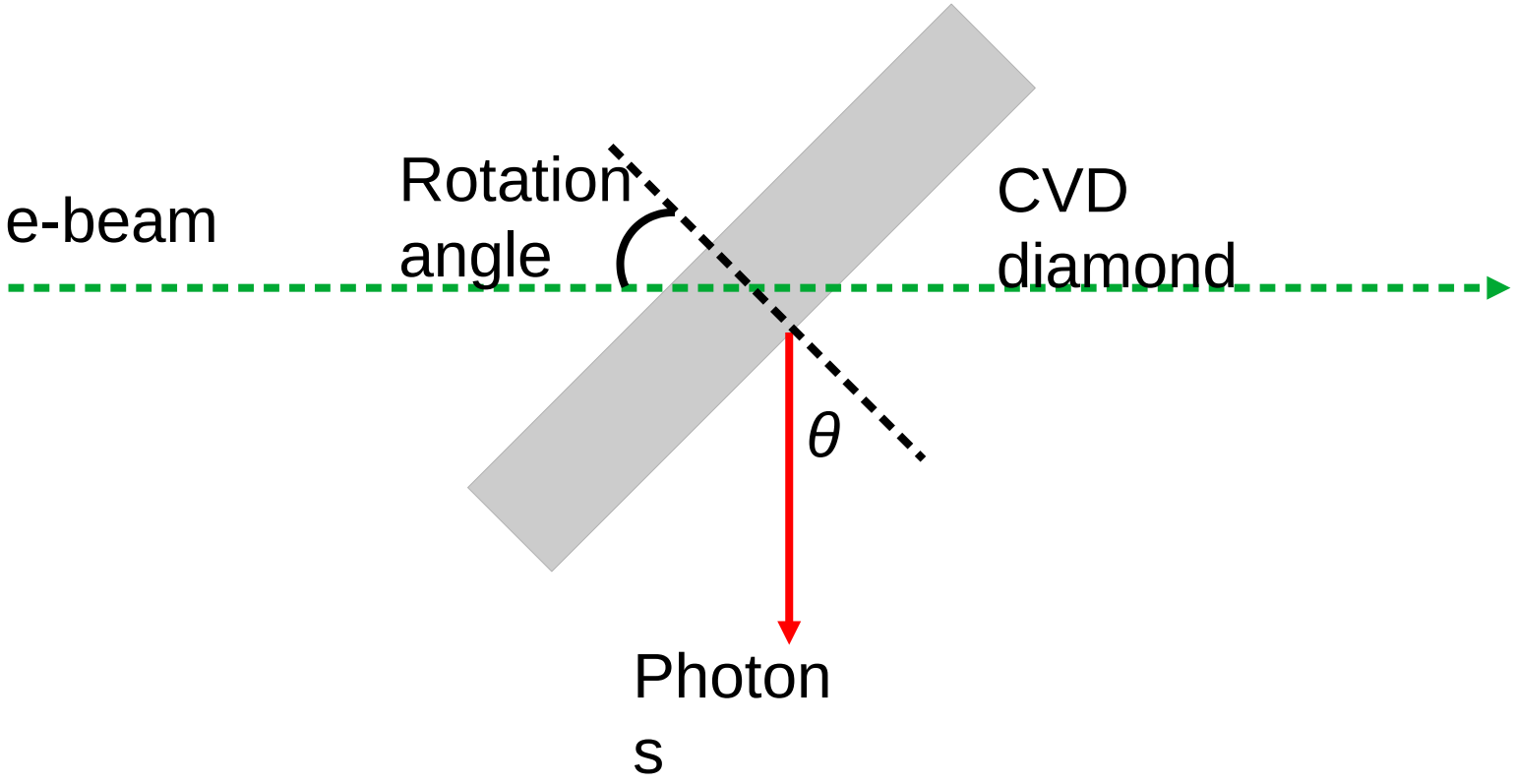

S.M. Seltzer and M.J. Berger, 1974. Vol. 119, P. 157–179.
R. Ito, P. Andreo, T. Tabata, Series A, Vol. 41, Issue 2, 1993, 69--76.

# Angle of incidence



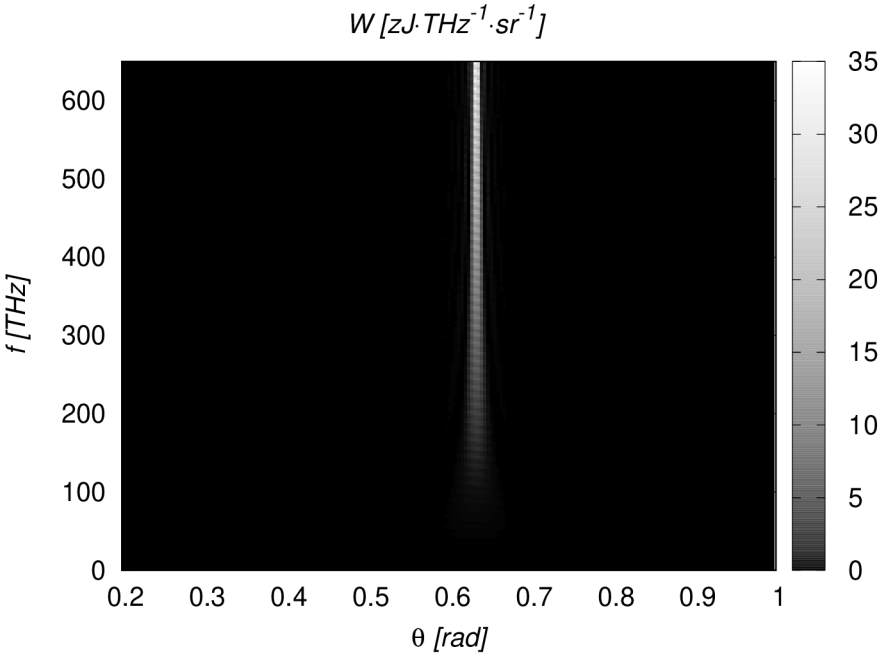

M.J. Berger, Transmission and reflection of electrons by aluminum foils, 1963. NBS TN187.

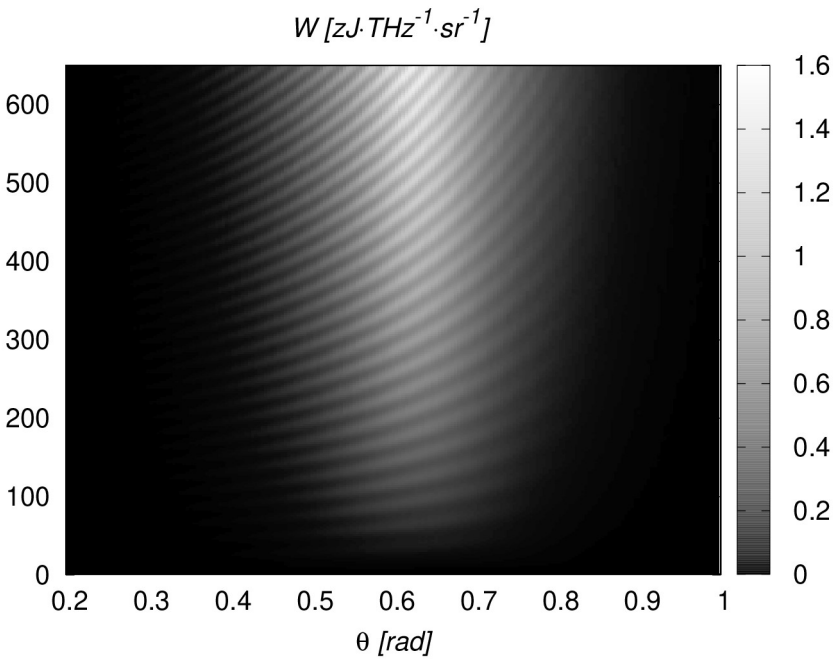
# Experimental scheme




Алексеев Б.А. и др. Письма в ЭЧАЯ. 2023. Т. 20. №1(246). С34-38

# Spectral-angular distribution



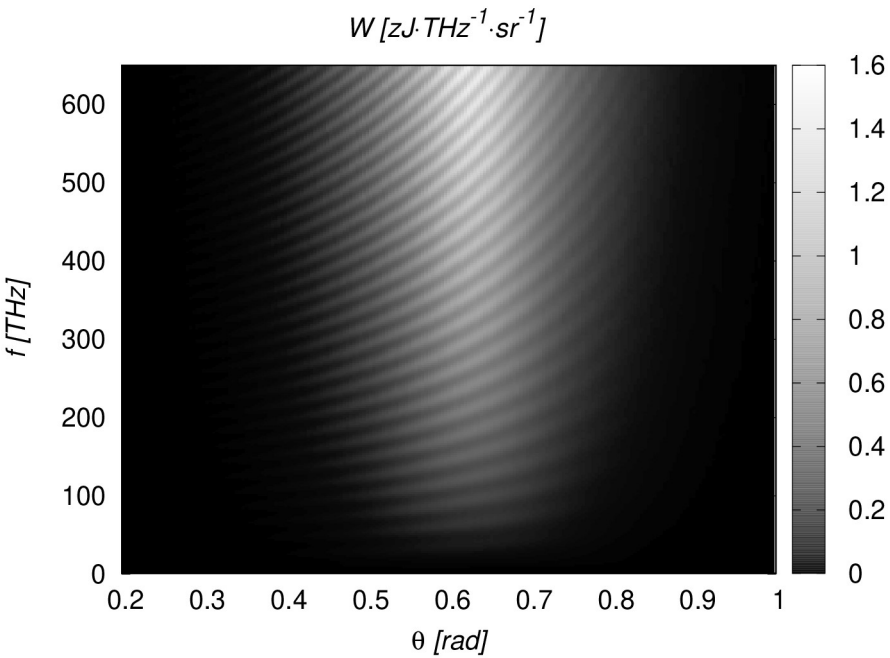




No multiple scattering
No energy losses

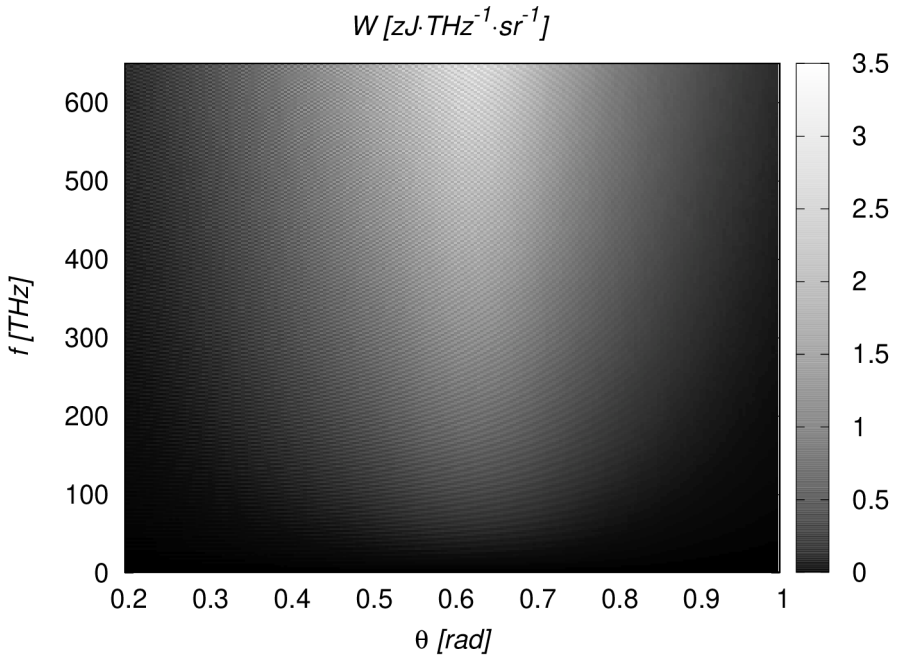
Kinetic enegy: 5.7 MeV
Angle: $\varphi \approx 53.7^{o}$
Index of refraction: n=2.57
Material: diamond
Thickness: **50 microns**

Multiple scattering
Energy losses

# Target thickness




50 microns




200 microns

Kinetic enegy: 5.7 MeV
Angle: $\varphi \approx 53.7^{o}$
Material: diamond

# Conclusions

Multiple scattering and energy losses suppress oscillations of spectral-angular distribution of Cherenkov’s radiation, broaden angular distribution of emitted photons and shifts the direction of radiation maximum towards the direction of electron velocity.

Thank you for the attention!!!