Effect of magnetic field on transition radiation.

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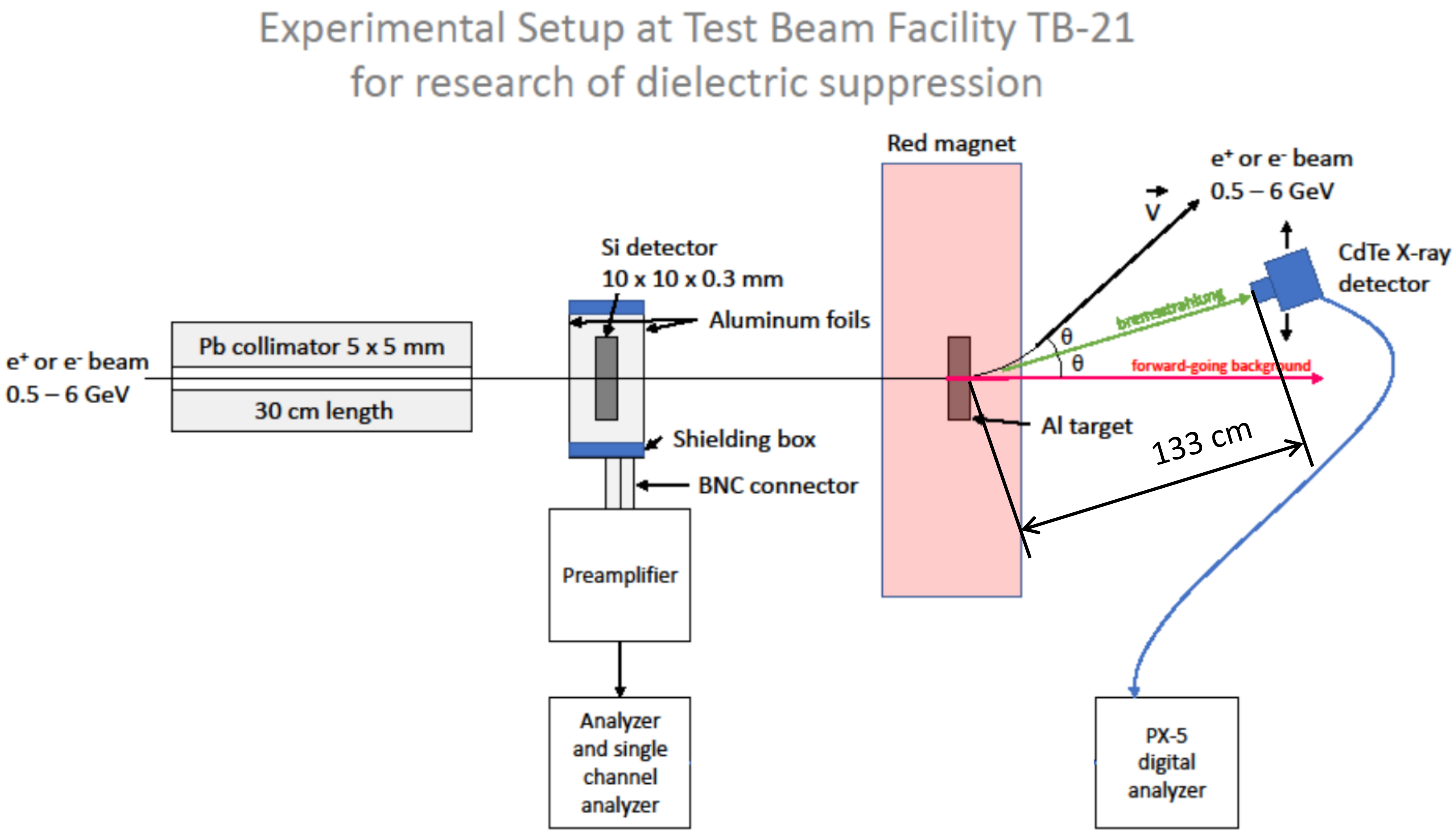
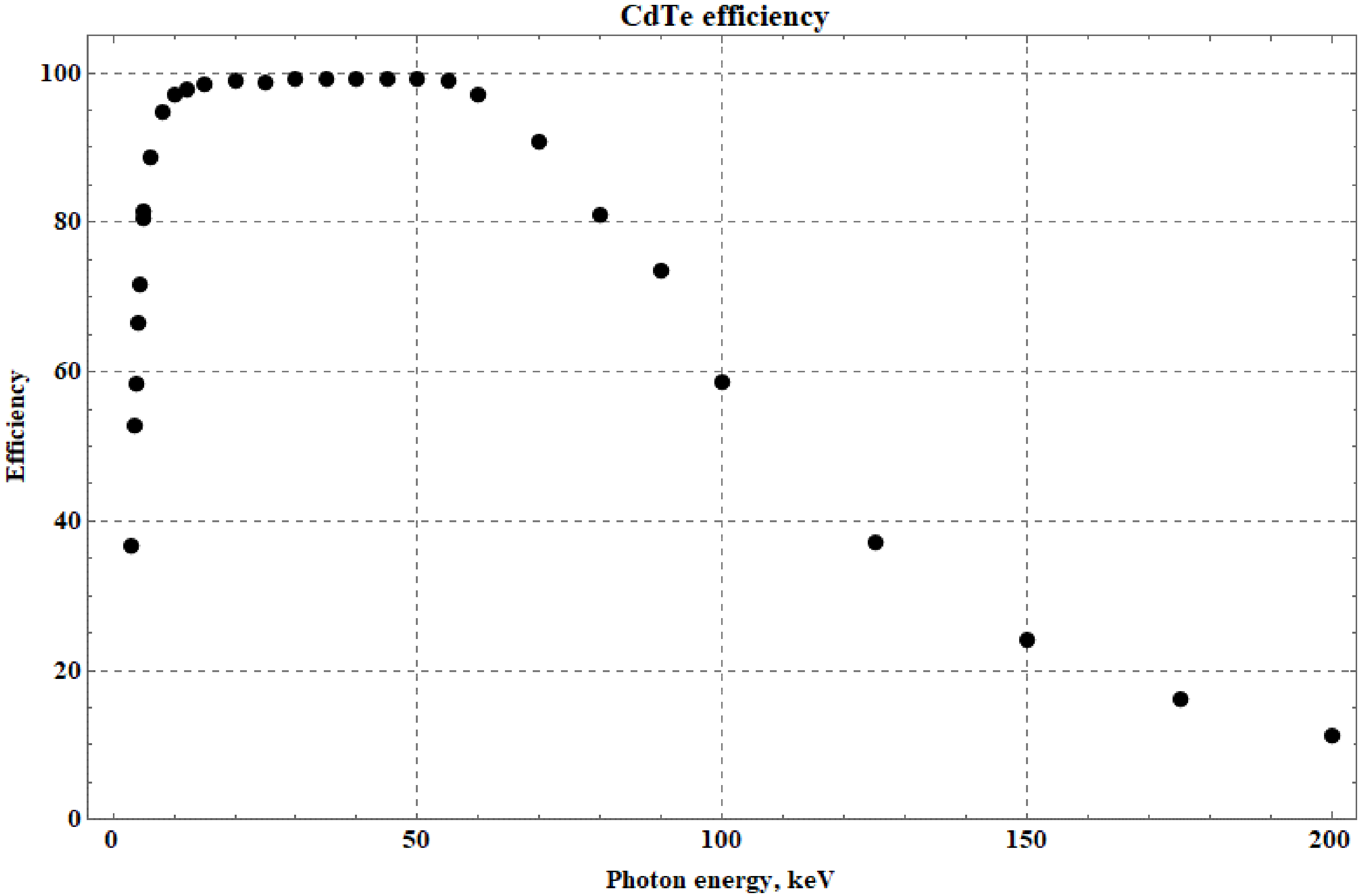
Experimental setup



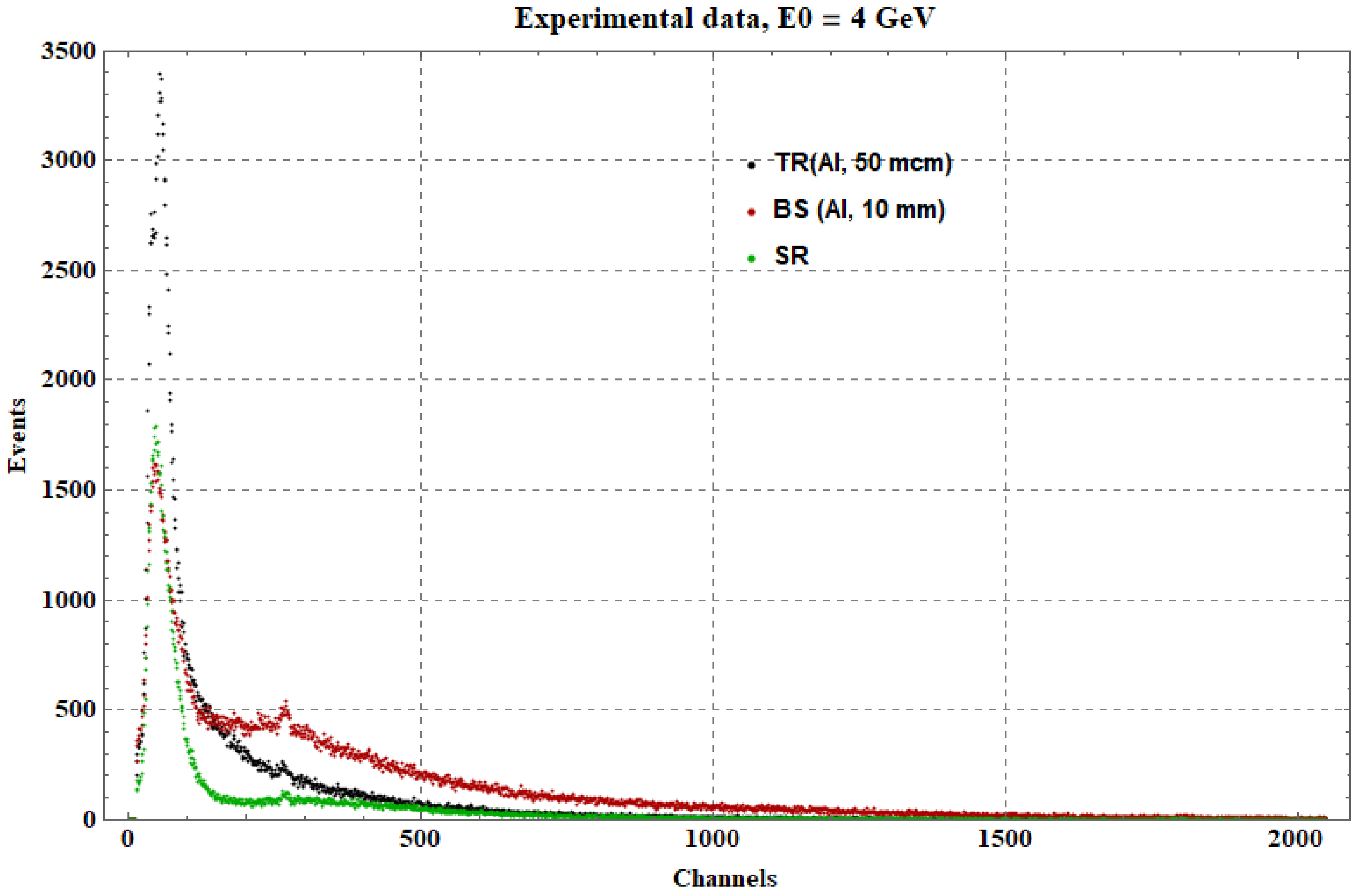
Efficiency of CdTe detector



Aperture 3 mm

Calibration dependence: $E_\gamma[keV] = 0.283\ i\ - 0.678$

Experimental data, E_0 = 4 GeV

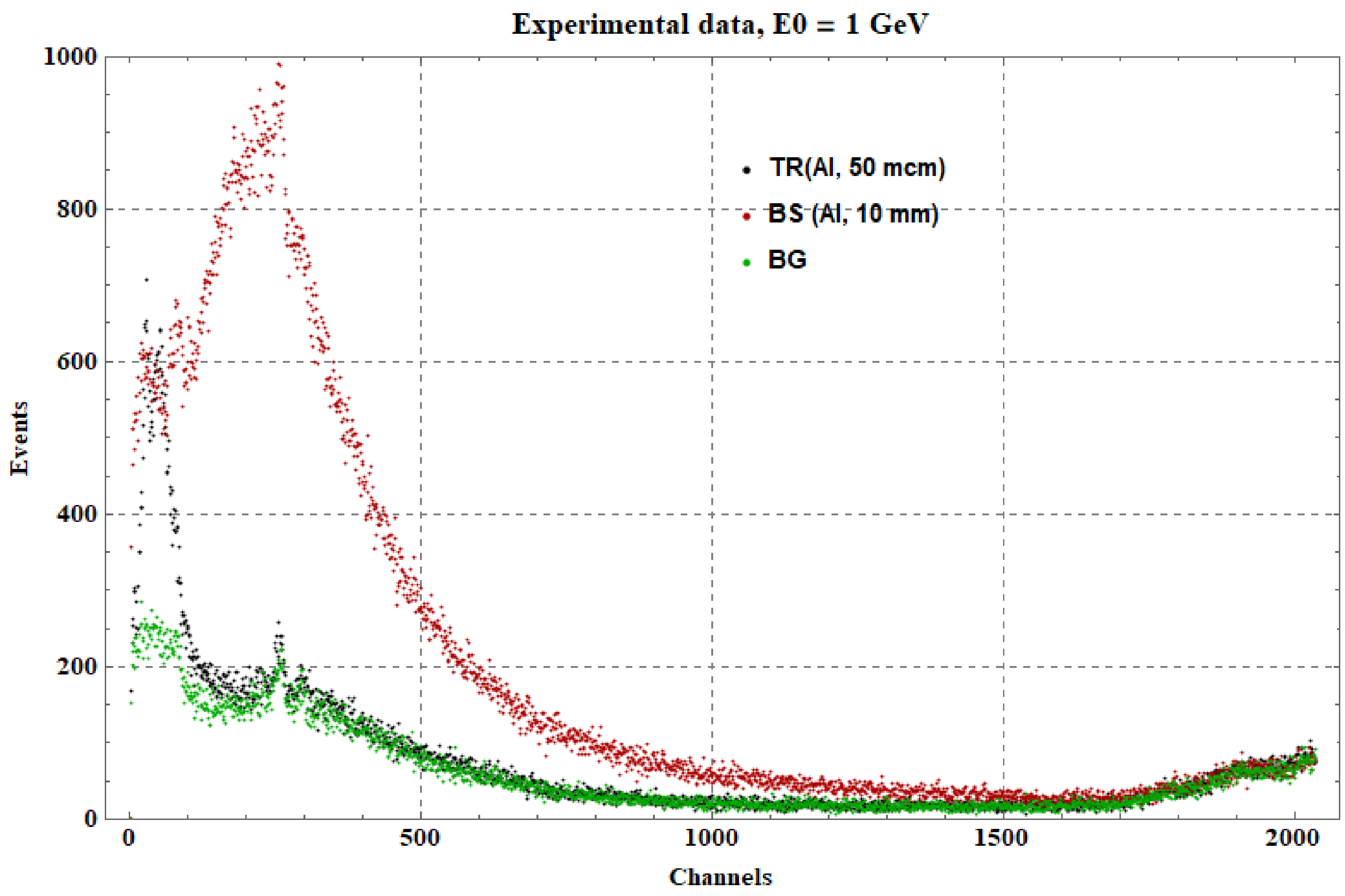


Peaks:

- $i = 269; \ E_\gamma = 75.449\ keV$
- $i = 260; \ E_\gamma = 72.90\ keV$

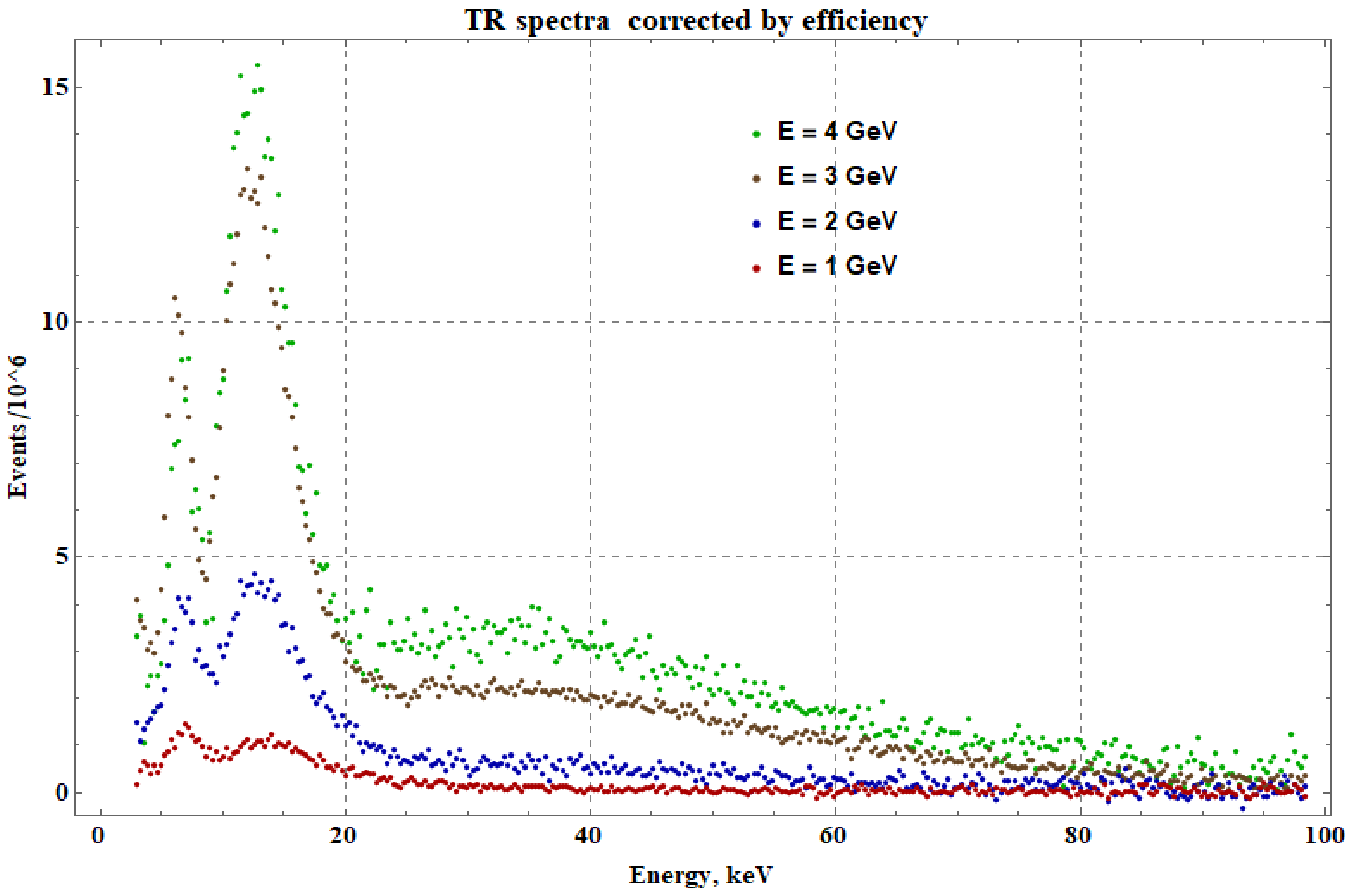
$k_{\alpha 1}, k_{\alpha 2}$ lines from lead

Experimental data, E_0 = 1 GeV



Measured TR spectra

1. Background subtraction
2. Normalization on 10^6 initial electrons
3. CdTe efficiency take into account



Transition radiation from a single surface

TR spectral – angular distribution

$$\frac{dW}{d\omega d\Omega} = \frac{\alpha}{4\pi^2}\gamma^2\left(\frac{\gamma\omega_p}{\omega}\right)^4 \frac{\gamma^2\theta^2}{\left(1+\gamma^2\theta^2\right)^2\left(1+\gamma^2\theta^2+\gamma^2\omega_p^2/\omega^2\right)^2}$$

, ωp – plasmon frequency

For Al ħ* ωp = 32.86 keV

TR intensity spectrum (in total cone):

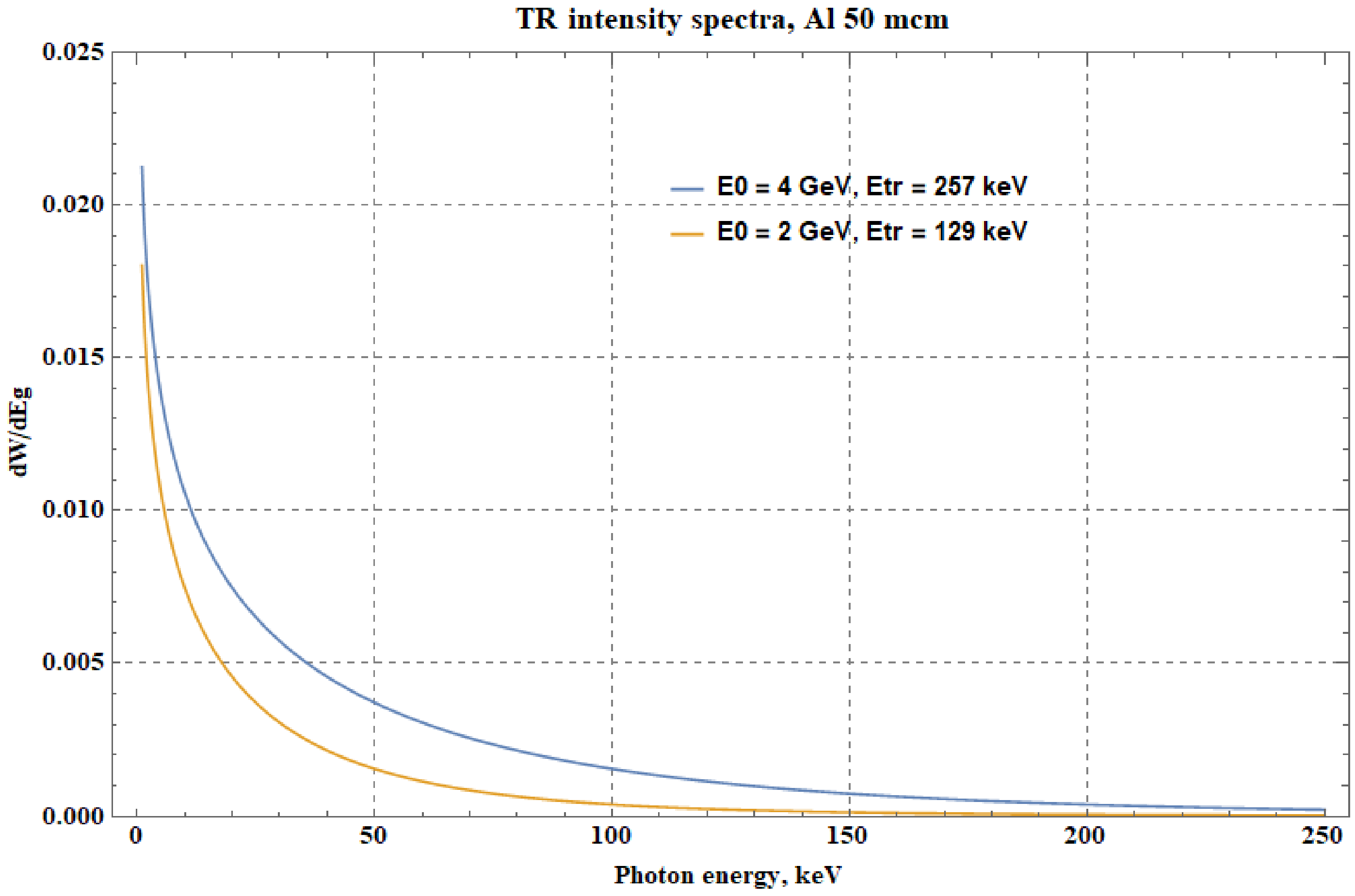
$$\frac{dW}{d\omega} = \frac{\alpha}{\pi}\left[\left(\frac{1}{2}+\frac{\omega^2}{\gamma^2\omega_p^2}\right)\ln\left(1+\frac{\gamma^2\omega_p^2}{\omega^2}\right)-1\right]$$

Emitted energy per electron:

$$W \approx \int_{2\omega_p}^{10\gamma\omega_p} \frac{dW}{d\omega}d\omega \approx 0{,}5\frac{\alpha}{\pi}\gamma\omega_p$$

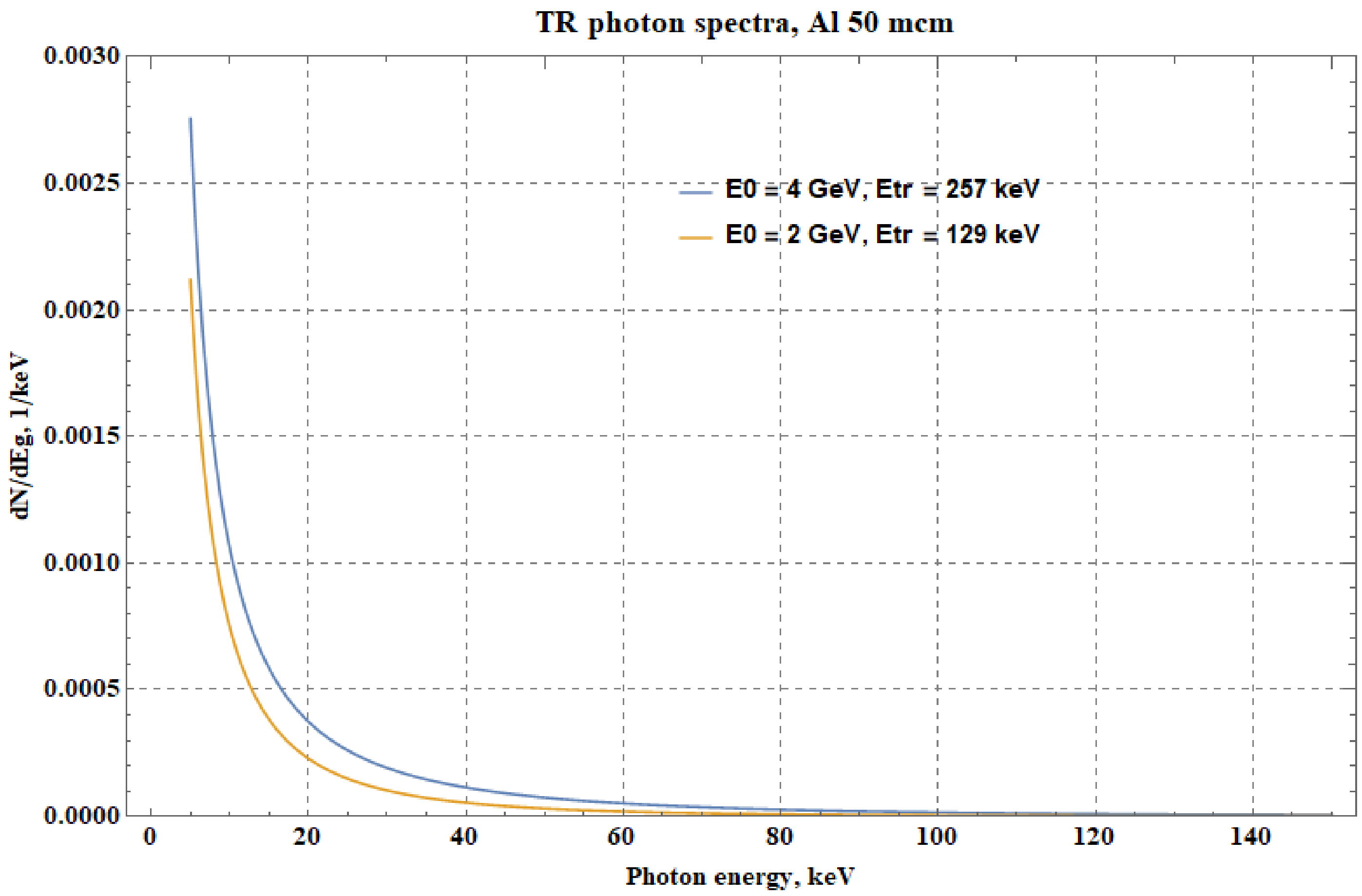
TR intensity spectra (total cone)

TR intensity spectra, *Al* foil



TR photon spectra (total cone)

TR photon spectra, *Al* foil



TR from a boundary between medium 1 and 2

$$\frac{d^2W_0}{\hbar d\omega d\Omega} = \frac{\alpha\omega^2\theta^2}{16\,\pi^2 c^2}(z_1 - z_2)^2,$$

formation zone $z_{1,2} = \frac{4\,c}{\omega}(\gamma^{-2} + \theta^2 + \omega_{1,2}^2/\omega^2)^{-1}$,

$\omega_{1,2}$ - plasmon frequency of the medium 1, 2.

For vacuum $\omega_1 = 0$:

$$z_1(\gamma = 8000, \hbar\omega = 10^4\ eV, \theta = \gamma^{-1}) = 2.56\ \times 10^3\ \ \mu m$$

For Al $\omega_2 = 32.86\ eV$:

$$z_2(\gamma = 8000, \hbar\omega = 10^4\ eV, \theta = \gamma^{-1}) = 0.08\ \ \mu m$$

TR from a foil into vacuum

$$\frac{d^2W_f}{\hbar d\omega d\Omega} = \frac{d^2W_0}{\hbar d\omega d\Omega}\left\{[1-\exp(-\mu_2 l_2/2)]^2 + 4\exp(-\mu_2 l_2/2) sin^2\frac{l_2}{z_2}\right\} = \frac{d^2W_0}{\hbar d\omega d\Omega}\ F_2.$$

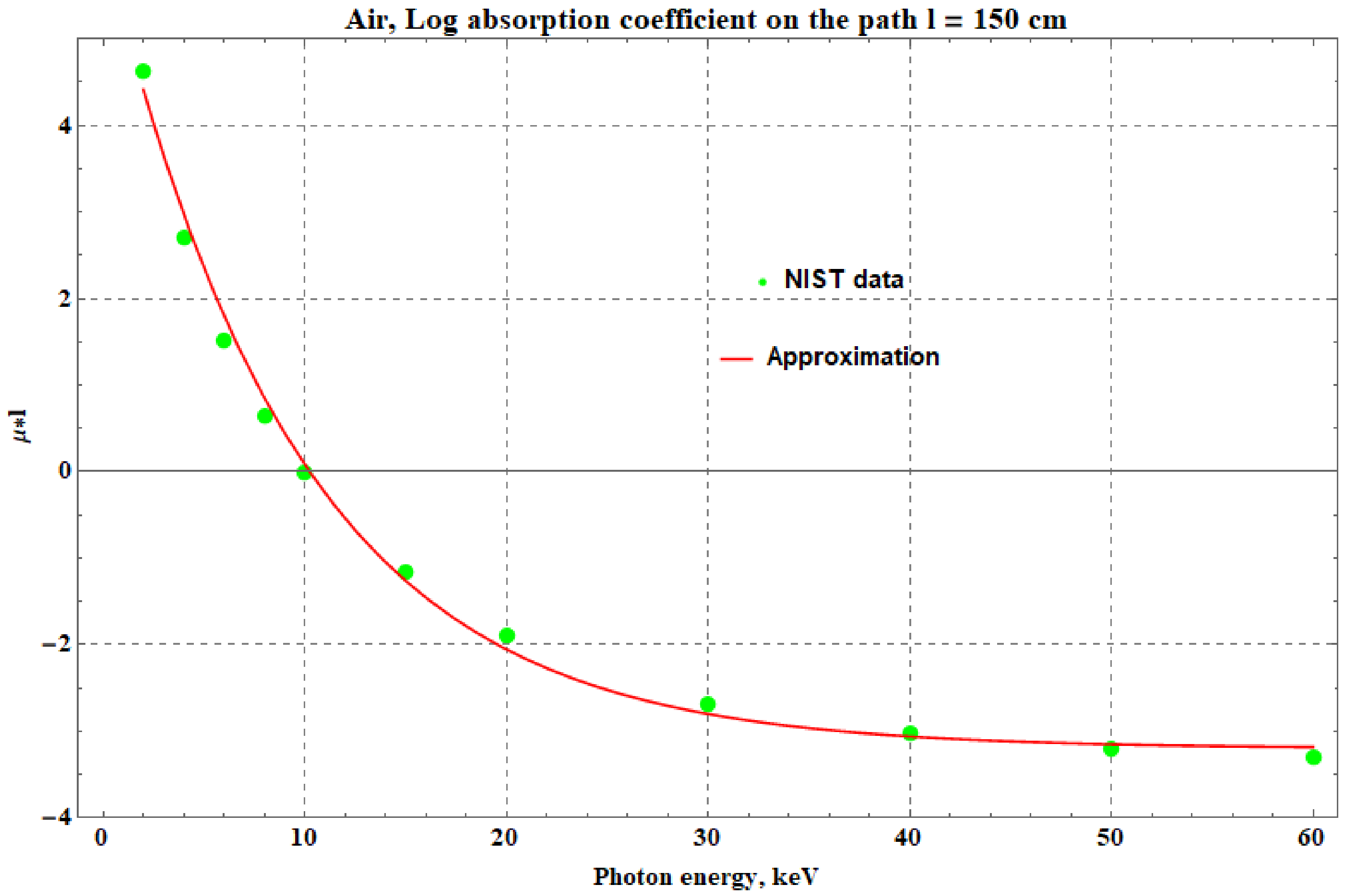
$$\frac{d^2W_0}{\hbar d\omega d\Omega} = \frac{\alpha}{\pi^2}\gamma^2\left(\gamma\omega_p/\omega\right)^4 \frac{\gamma^2\theta^2}{(1+\gamma^2\theta^2)\left(1+\gamma^2\theta^2+\ \left(\gamma\omega_p/\omega\right)^2\right)}$$

l_2 - foil thickness,

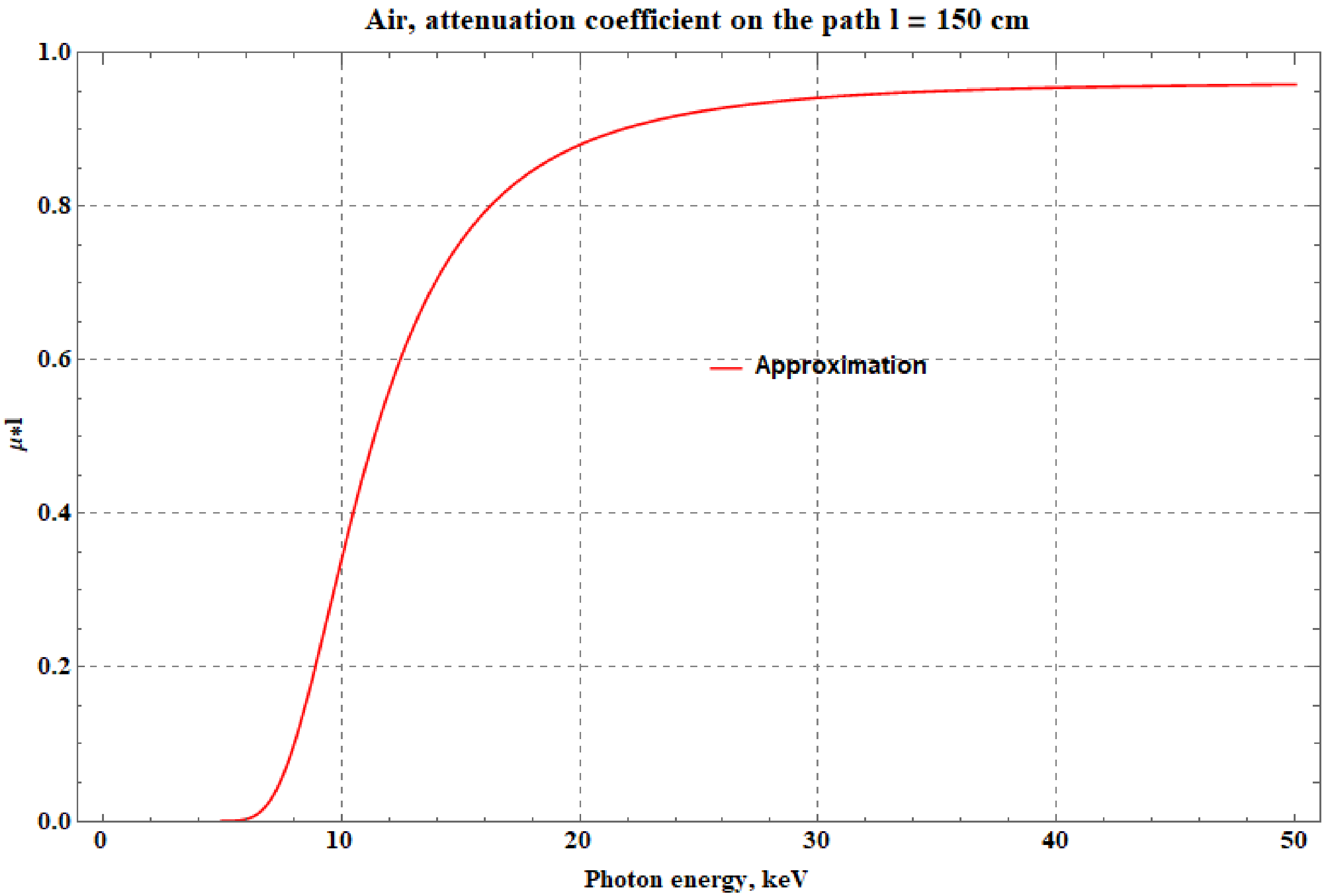
μ_2^{-1} - X-ray attenuation length at the photon energy $\hbar\omega$,

F_2 - interference function

X ray absorption in air (L = 130 cm)



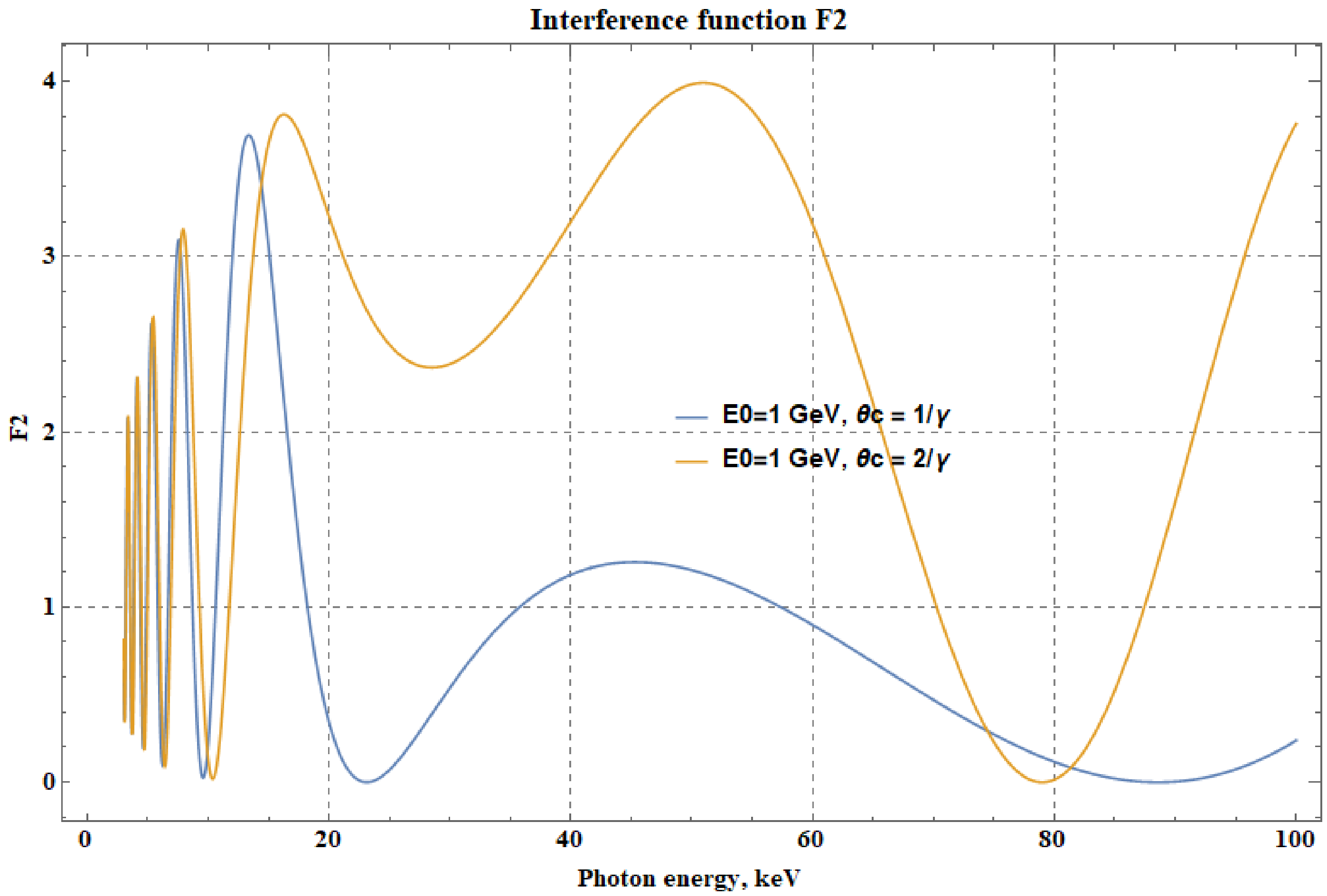
X ray attenuation in air (L = 130 cm)



Interference function F_2

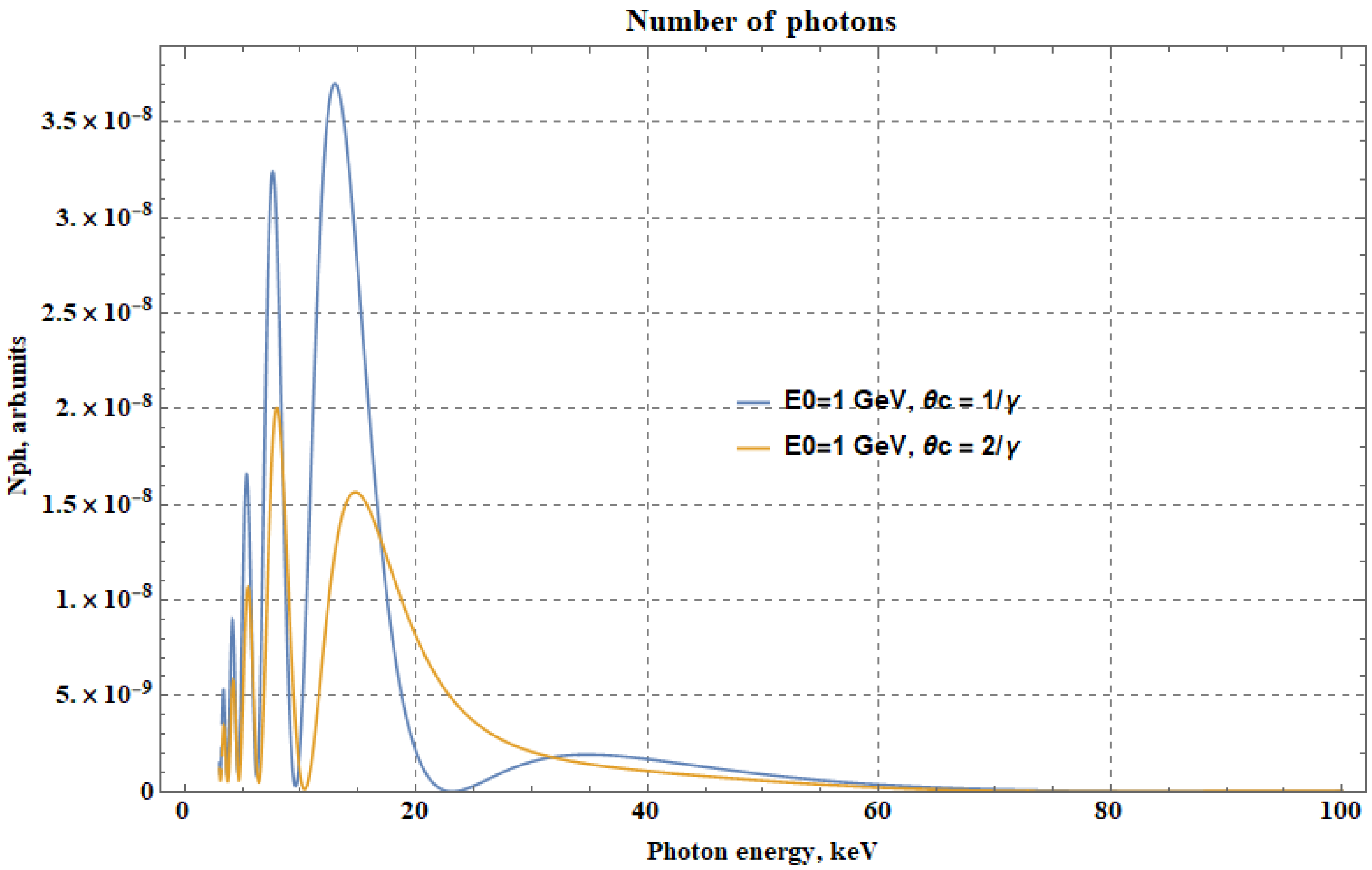
Foil thickness - $l_2 = 53\ \mu m$

Plasmon frequency - $\omega_2 = 29.5\ eV$



Spectral-angular TR distribution

Attenuation in air taken into account



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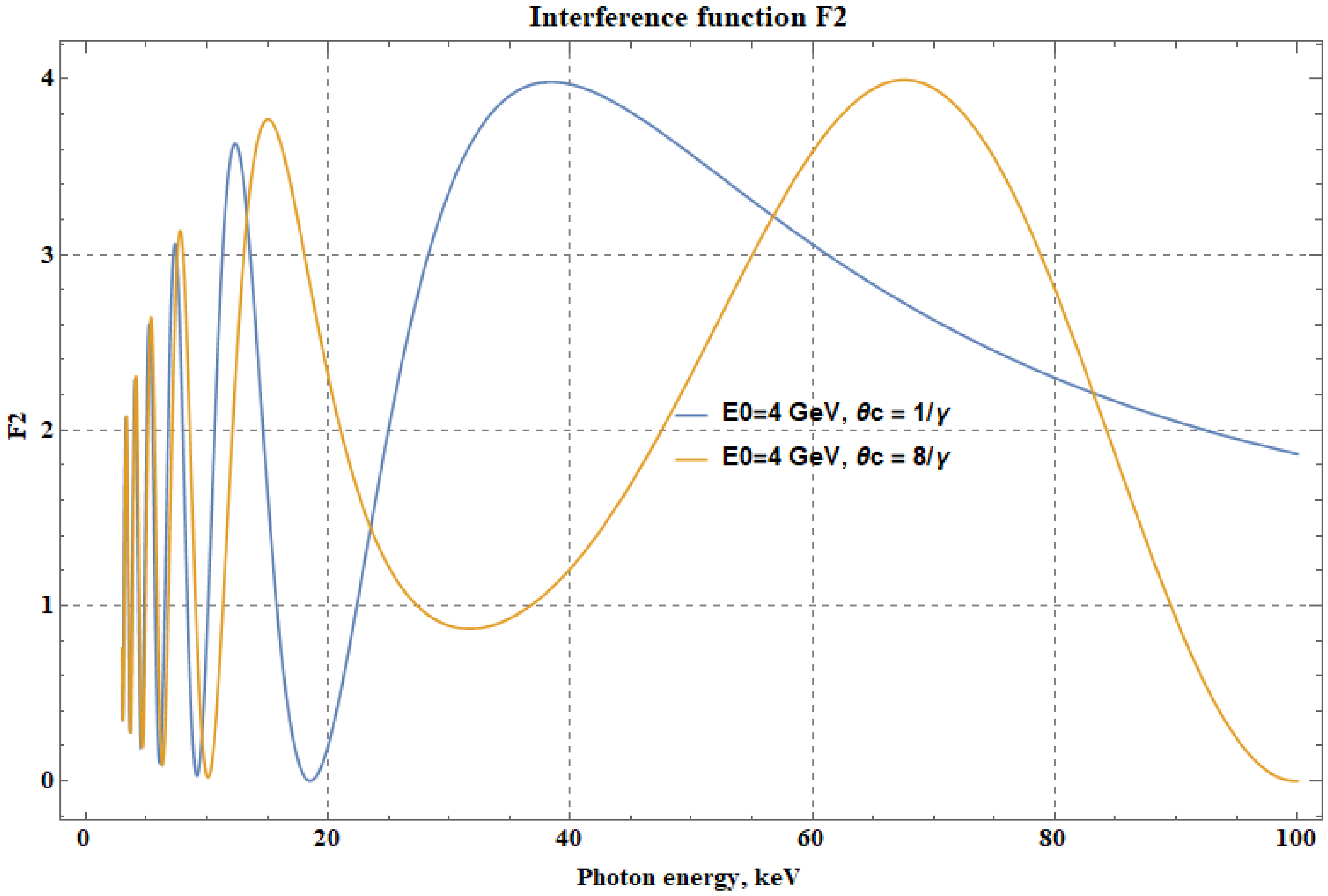
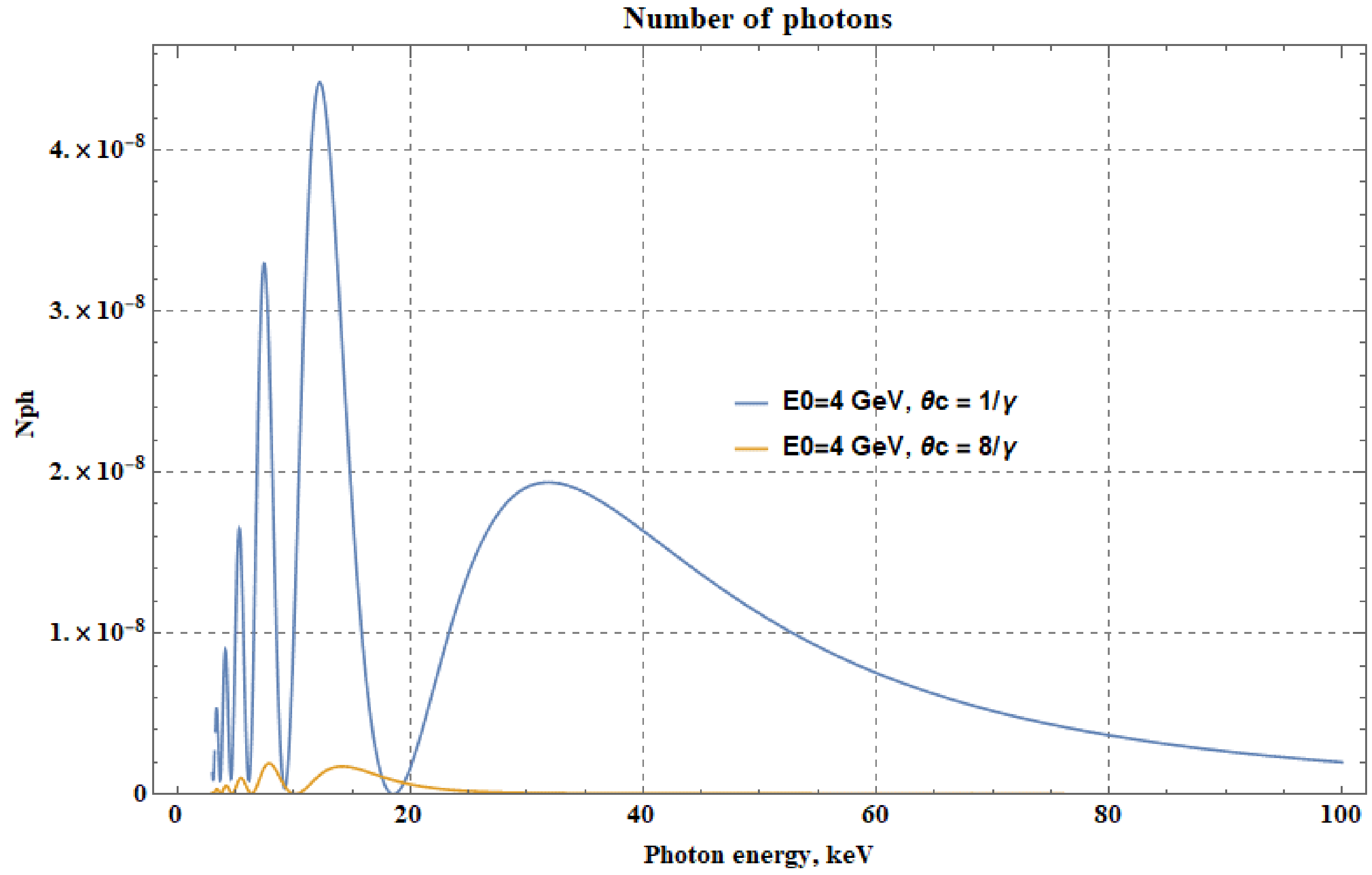


Spectral-angular TR distribution

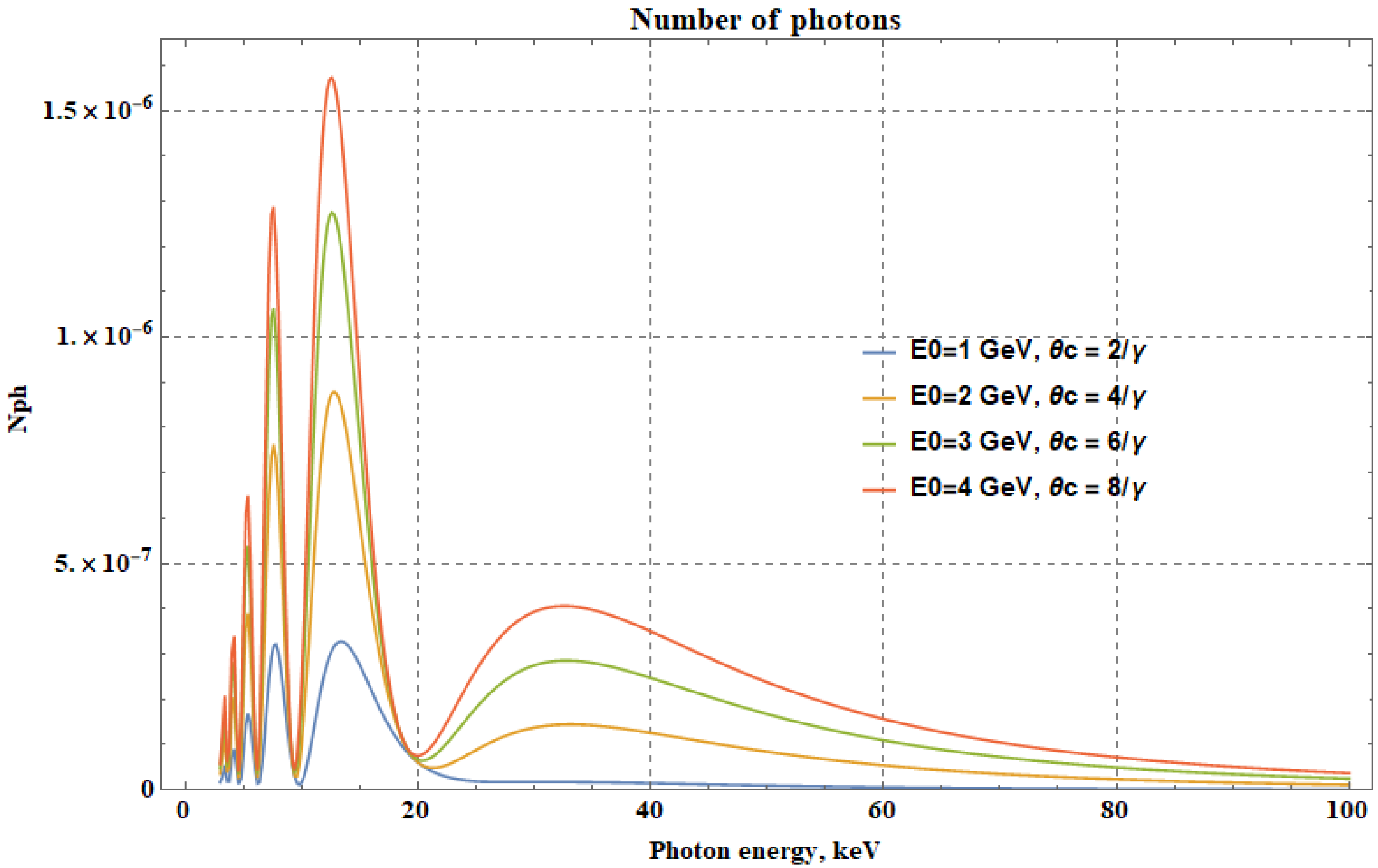
Attenuation in air taken into account



Collimated TR photon spectrum

$$\frac{dN_f}{\hbar d\omega} = \frac{2\alpha}{\pi} \left(\frac{\gamma\omega_p}{\omega}\right)^4 \frac{1}{E_\gamma} \int_0^{tc} t\, dt\, \frac{t^2\, F_2}{(1+\ t^2)^2 \left(1 + t^2 + \left(\gamma\omega_p/\omega\right)^2\right)^2}$$

TR photon spectra for $\theta c = 1\, mrad$

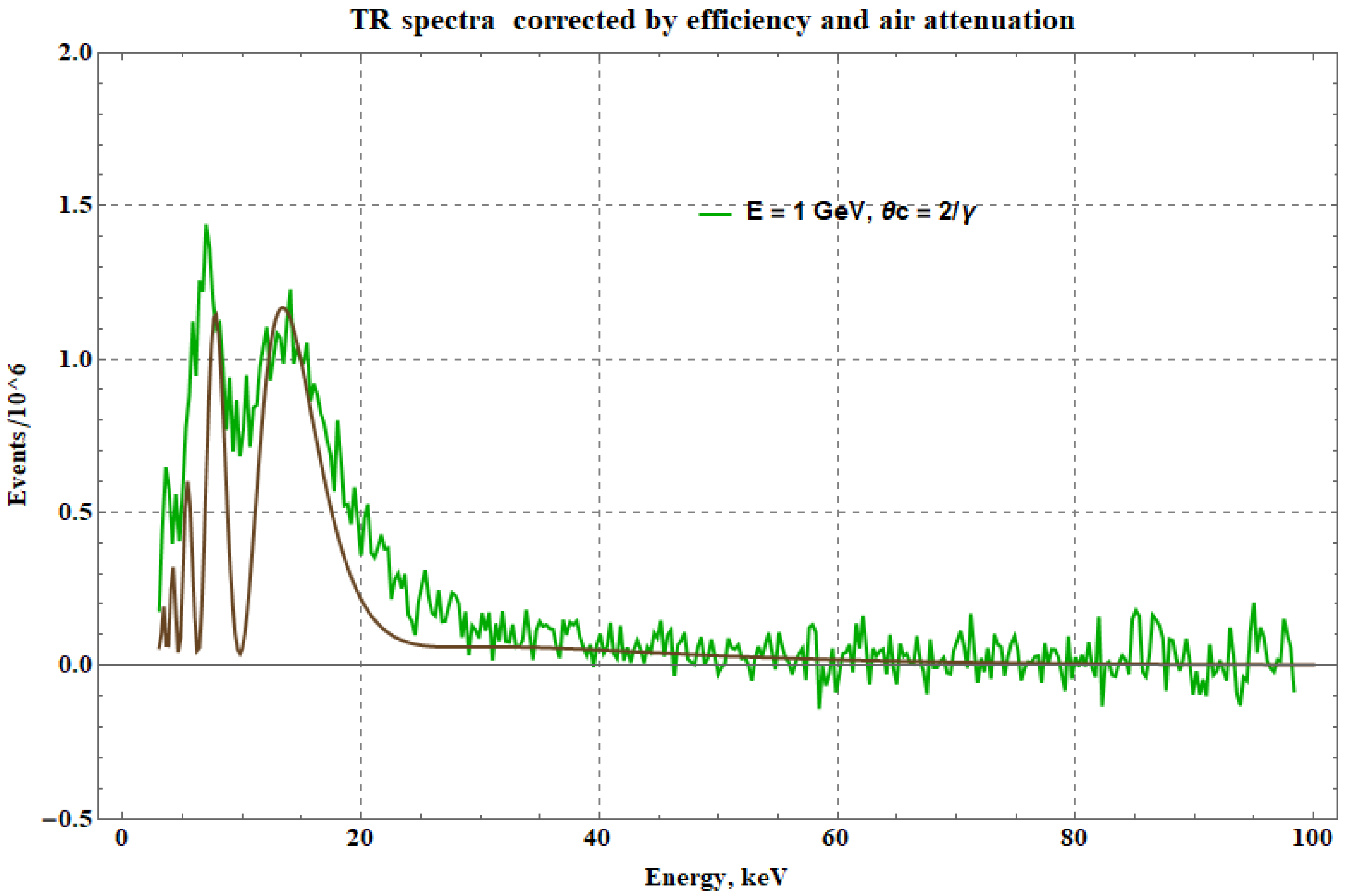


Comparison of measured and calculated TR spectra ($E_0 = 1$ GeV)

Calculated TR photon spectrum

$$\frac{dN_{comp}}{\hbar d\omega} = Norm \frac{dN_t}{\hbar d\omega},$$

$$Norm = 3.57 \times 10^6$$

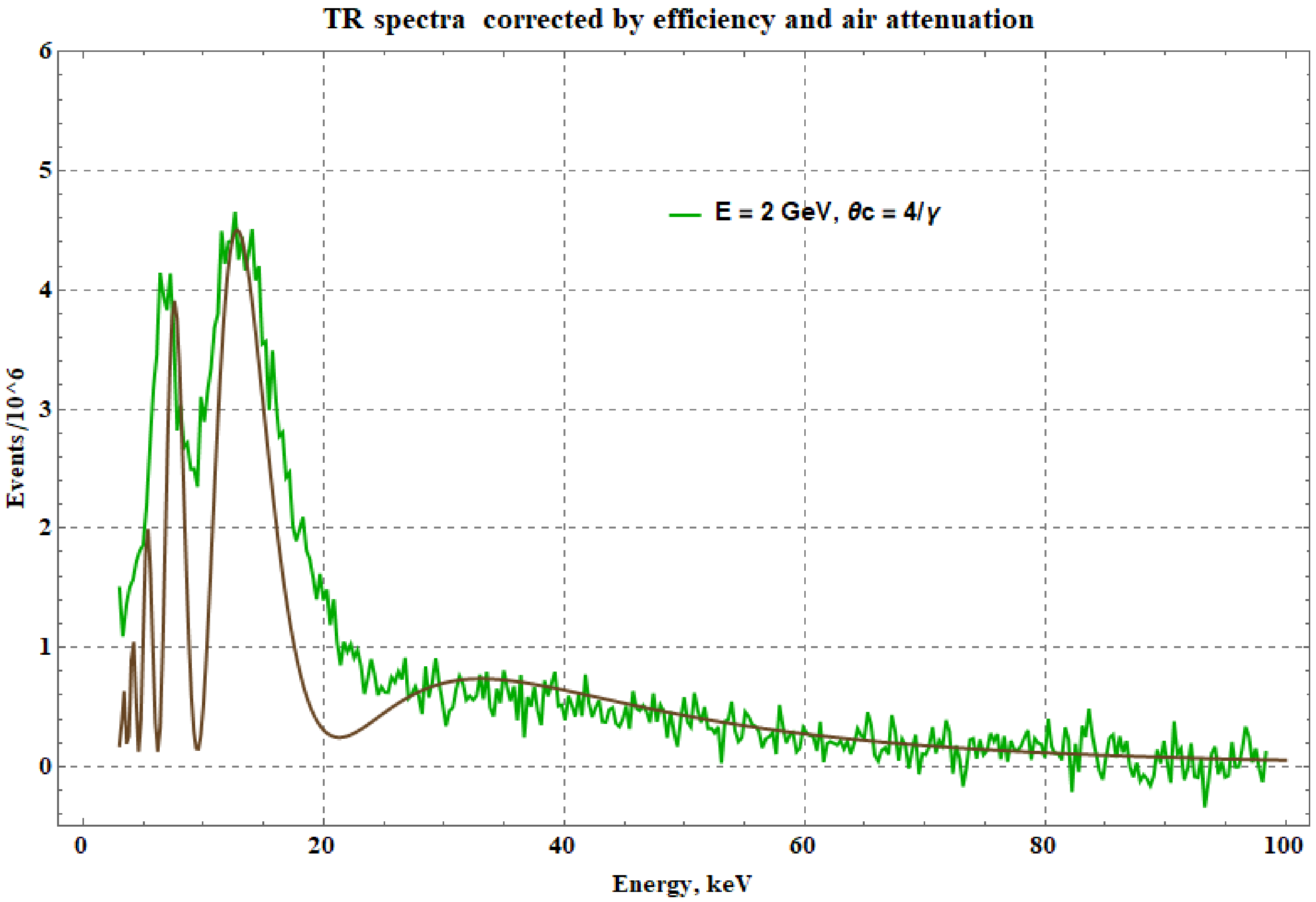


Comparison of measured and calculated TR spectra ($E_0 = 2$ GeV)

Calculated TR photon spectrum

$$\frac{dN_{comp}}{\hbar d\omega} = Norm \frac{dN_t}{\hbar d\omega},$$

$$Norm = 5.12 \times 10^6$$

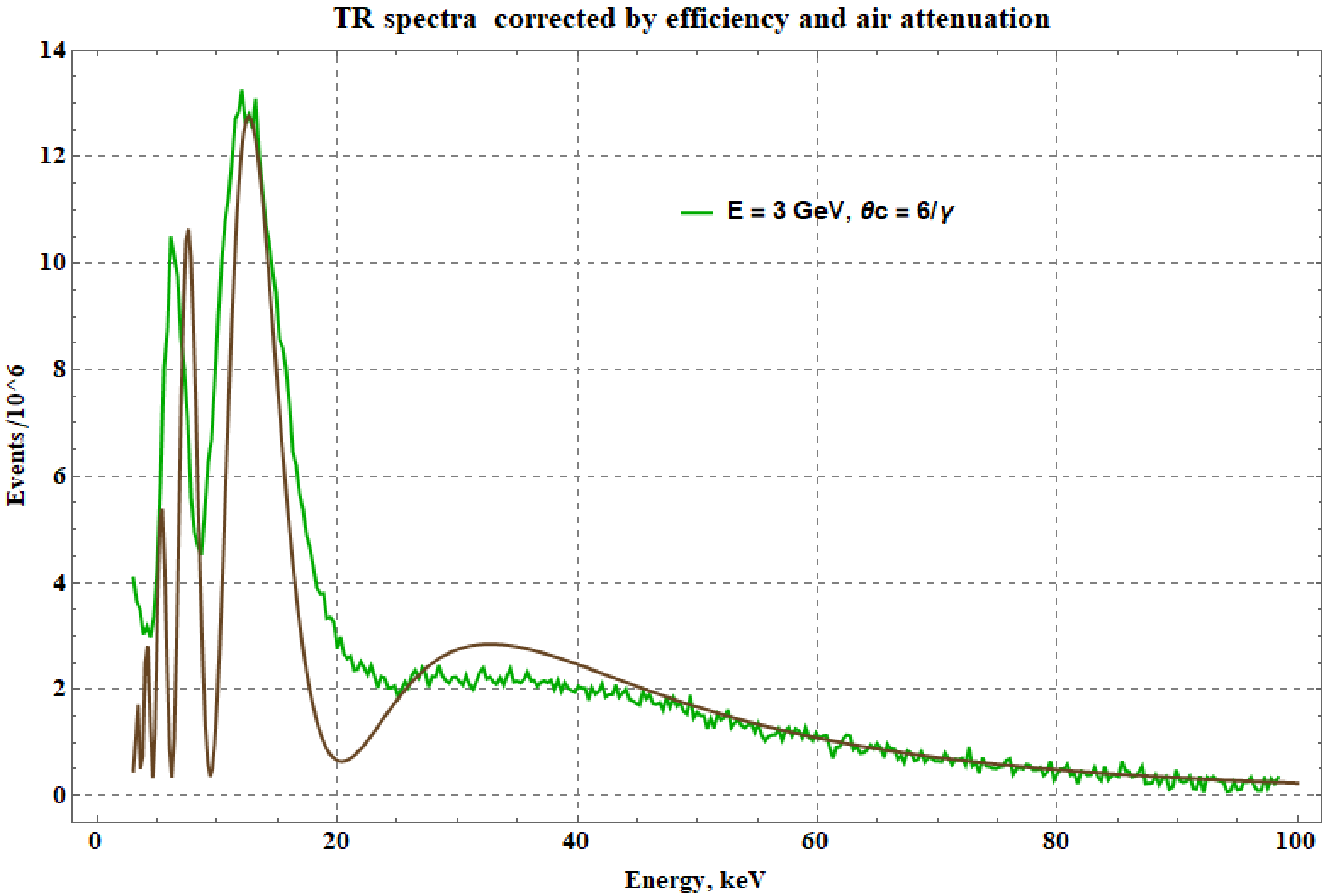


Comparison of measured and calculated TR spectra (E_0 = 3 GeV)

Calculated TR photon spectrum

$$\frac{dN_{comp}}{\hbar d\omega} = Norm\frac{dN_t}{\hbar d\omega},$$

$$Norm = 1.07 \times 10^7$$

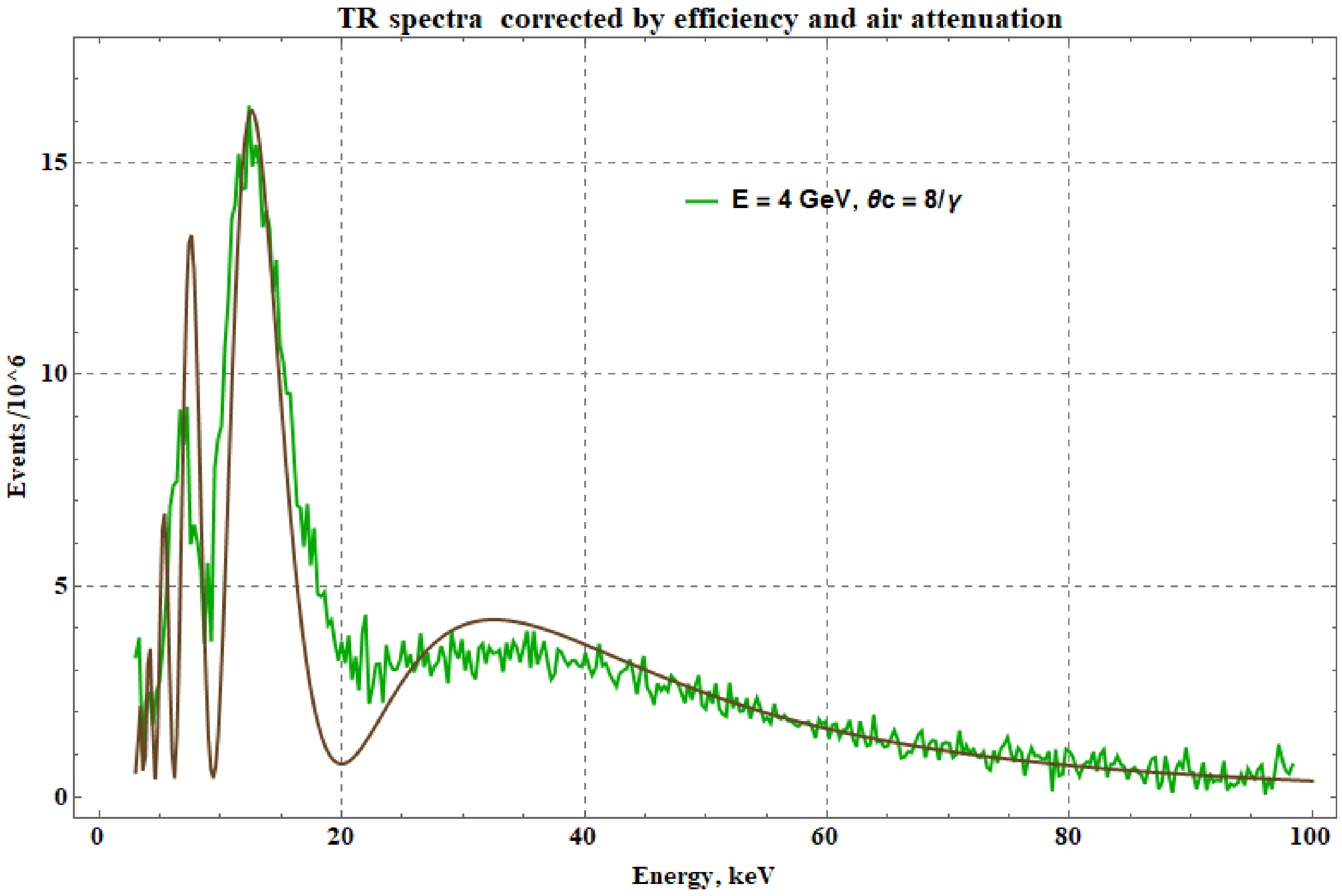


Comparison of measured and calculated TR spectra ($E_0 = 4$ GeV)

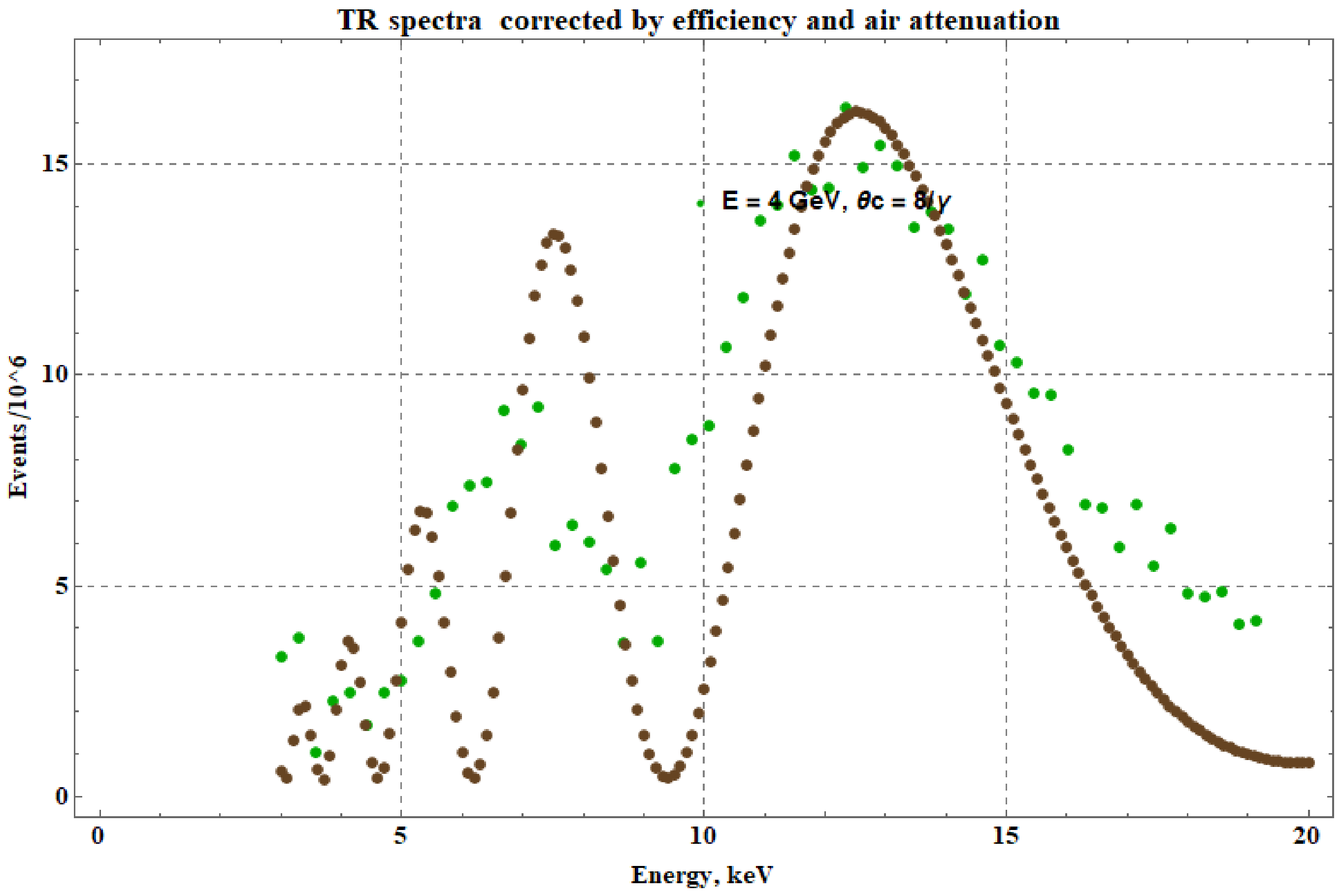
Calculated TR photon spectrum

$$\frac{dN_{comp}}{\hbar d\omega} = Norm\frac{dN_t}{\hbar d\omega},$$

$$Norm = 1.13 \times 10^7$$



Comparison of measured and calculated TR spectra (E_0 = 4 GeV)



Deviation of the electron trajectory from a rectilinear one

Electron bending angle θ_B by magnetic field *B* in a TR formation length l_f:

$$l_f = \frac{2\,c}{\omega\,(\gamma^{-2} + \theta^2 + \omega_2^2/\omega^2)} = \frac{z_2}{2}; \qquad \theta_{\boldsymbol{B}} \sim \frac{l_F}{R},$$

R – orbit radius, in our scheme *R = const = 17.33 m*

If $\theta_B \sim \gamma^{-1}$ then TR may be suppressed (in analogy with LPM).

For $E_0 = 4\,GeV,\;\; \hbar\omega = 8\,keV{:}\quad l_f = 1.6\,mm;\quad \theta_B = 0.092\,mrad;\quad \gamma\theta_B = 0.74$

For $E_0 = 3\,GeV,\;\; \hbar\omega = 8\,keV{:}\quad l_f = 0.9\,mm;\quad \theta_B = 0.052\,mrad;\quad \gamma\theta_B = 0.31$

Interference function F3 for a multifoil target

$$\frac{d^2W_{mf}}{\hbar d\omega d\Omega} = \frac{d^2W_f}{\hbar d\omega d\Omega} \times \frac{sinh^2\left[\frac{N}{4}(\mu_1 l_1 + \mu_2\, l_2)\right] + sin^2\left[N\left(\frac{l_1}{z_1} + \frac{l_2}{z_2}\right)\right]}{sinh^2\left[\frac{1}{4}(\mu_1 l_1 + \mu_2\, l_2)\right] + sin^2\left[\frac{l_1}{z_1} + \frac{l_2}{z_2}\right]} = \frac{d^2W_0}{\hbar d\omega d\Omega} F_2 F_3,$$

Function F_3 depends on the radiation length explicitly

l_1 - gap width of multifoil target

μ_1^{-1} - attenuation length in air

N – number of periods

Conclusion

- Investigations of TR characteristics from a foil placed in magnetic field allowed to suppress background level and to measure spectra with reasonable accuracy
- Measurements were performed for electron energies E_0 = 1,2,3,4 GeV by CdTe detector with aperture 1.15 mrad
- We measured TR spectra from 53 um Al foil and BG spectra without foil
- Measured TR spectra for E_0 = 1,2,3 GeV are in good agreement with calculated ones if Al plasmon energy is equal to 29.5 keV (table value is 32.86 keV)
- For E_0 = 4 GeV intensity of the TR peak with energy~ 8 keV is much less than predicted one
- Magnetic suppression of TR can be considered as a possible explanation of the observed effect