Feasibility of X-ray Cherenkov Diffraction radiation for beam diagnostics of linear accelerators

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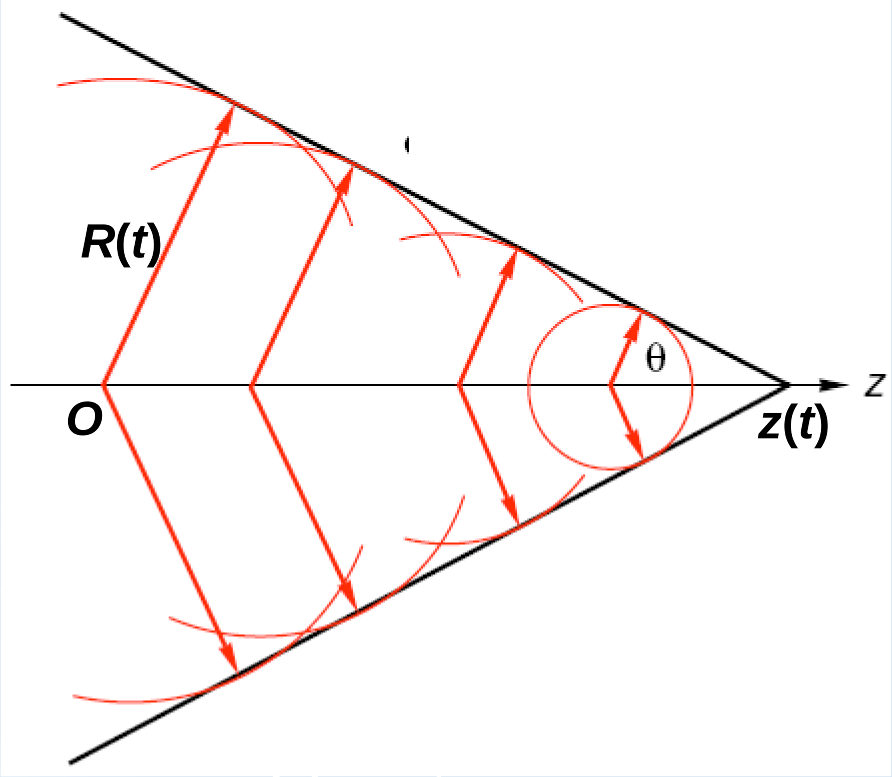
Introduction

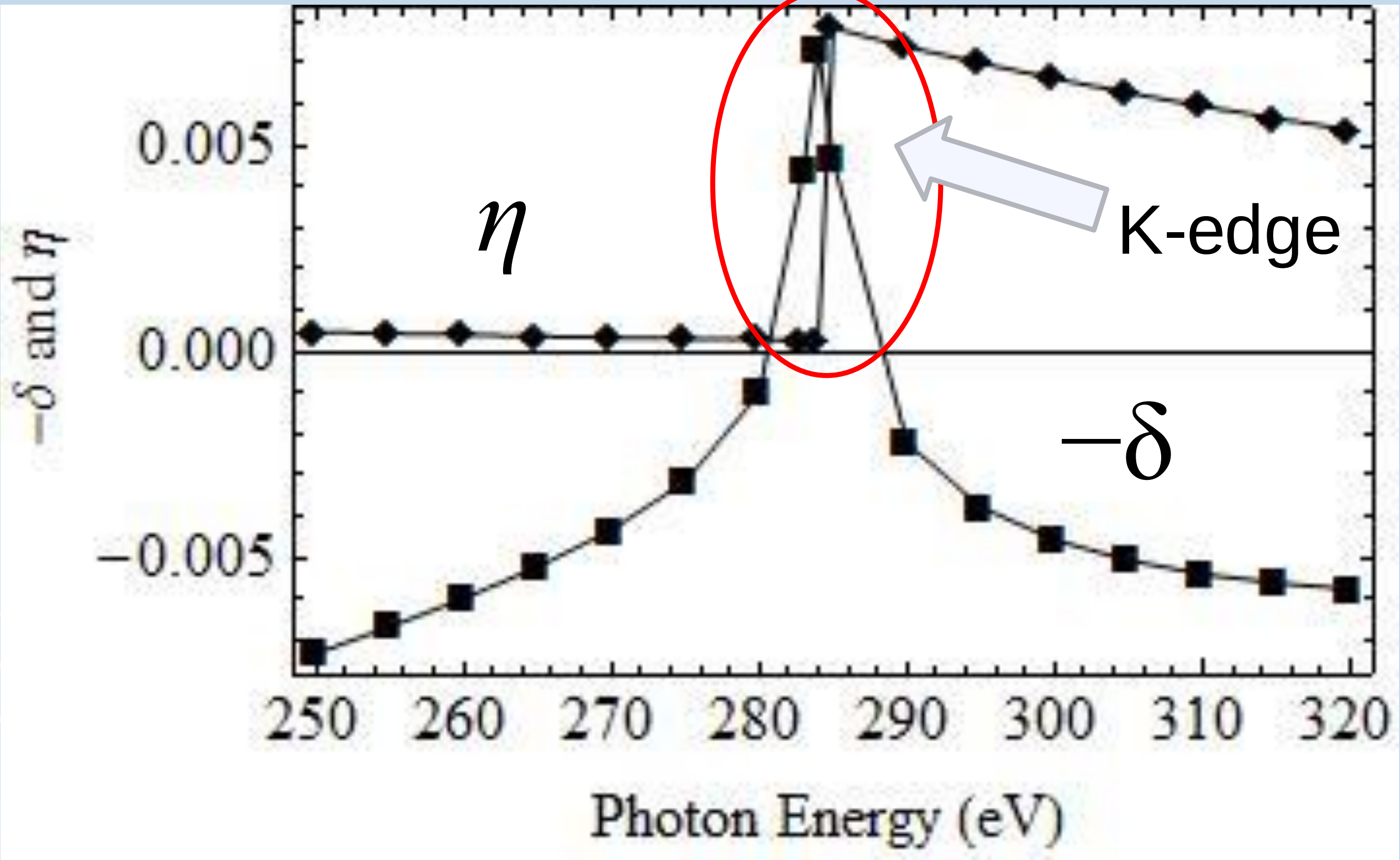


Cherenkov Radiation is generated whenever the charged particle velocity is larger than the phase velocity of light

$$\cos\theta = \frac{R(t)}{z(t)} = \frac{(c/n)t}{vt} = \frac{1}{\beta n}$$

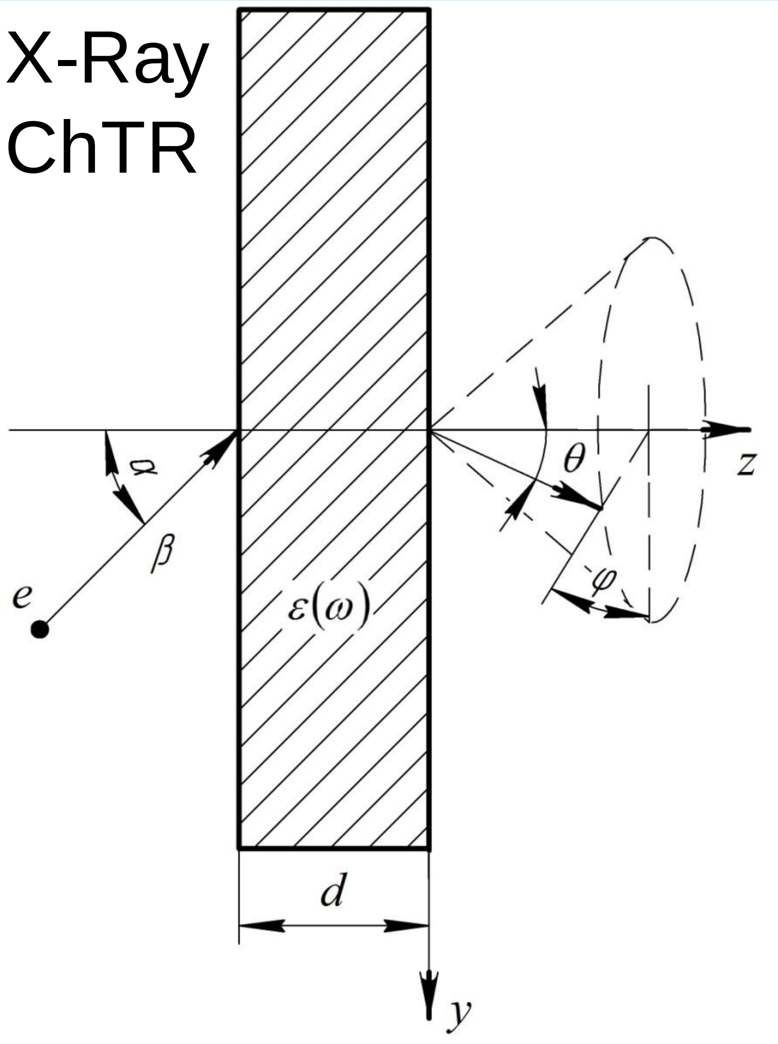
Is there Cherenkov radiation in X-ray region?

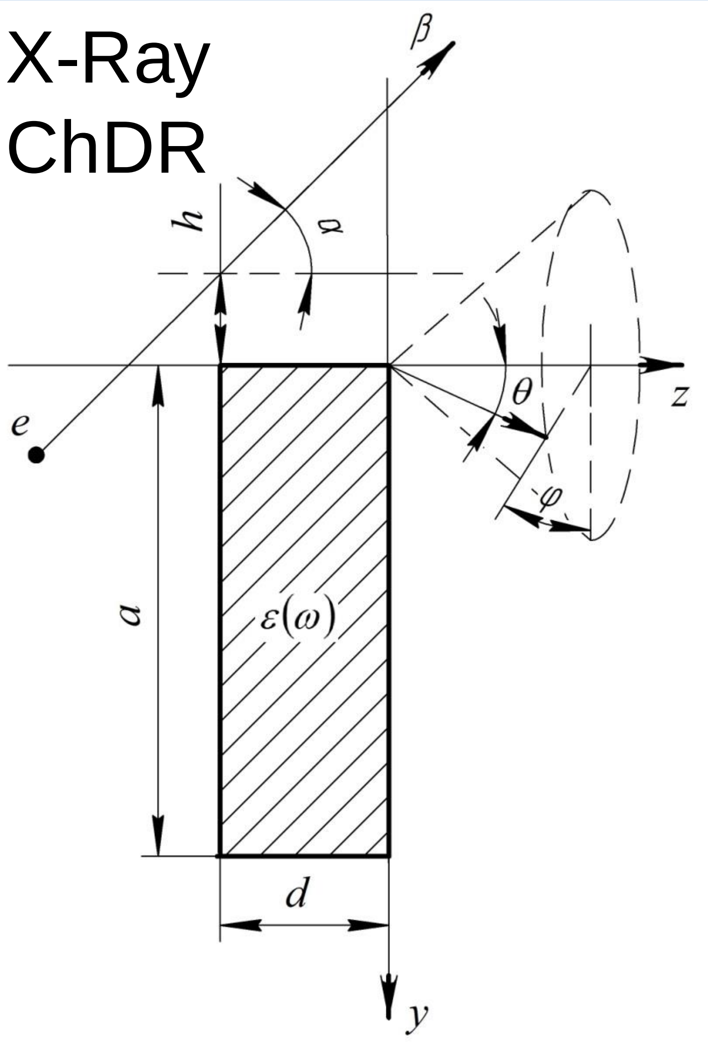
Carbon Dielectric Permittivity



$$\tilde{n} = \sqrt{e(w)} = \sqrt{1- d+ih}$$

Geometry





Theoretical Approach

The theoretical approach is based on the method of polarization currents. For a non-magnetic medium the density of the polarization currents in a right hand side of the Maxwell's equations

$$\mathbf{j}_{pol} = \sigma(\omega)\left(\mathbf{E}^0 + \mathbf{E}^{pol}(\mathbf{j}_{pol})\right)$$

where conductivity is

$$\sigma(\omega) = \frac{i\omega}{4\pi}\left(1-\varepsilon(\omega)\right)$$

The field of the Polarization Radiation (PR) emitted by medium atoms excited (polarized) by the external field of the passing particle moving rectilinearly and with constant velocity in a substance (or in its vicinity) can be represented as a solution of Maxwell equations

$$\mathbf{H}^{pol}(\mathbf{r},\omega) = \mathrm{curl}\frac{1}{c}\int_{V_T}\sigma(\omega)\mathbf{E}^0(\mathbf{r}',\omega)\frac{\exp\left(i\sqrt{\varepsilon(\omega)}\left|\mathbf{r}'-\mathbf{r}\right|\omega/c\right)}{\left|\mathbf{r}'-\mathbf{r}\right|}d^3r'$$

X-Ray Cherenkov Transition Radiation

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X-RAY CHERENKOV RADIATION AS A SOURCE FOR RELATIVISTIC CHARGED PARTICLE BEAM DIAGNOSTICS*

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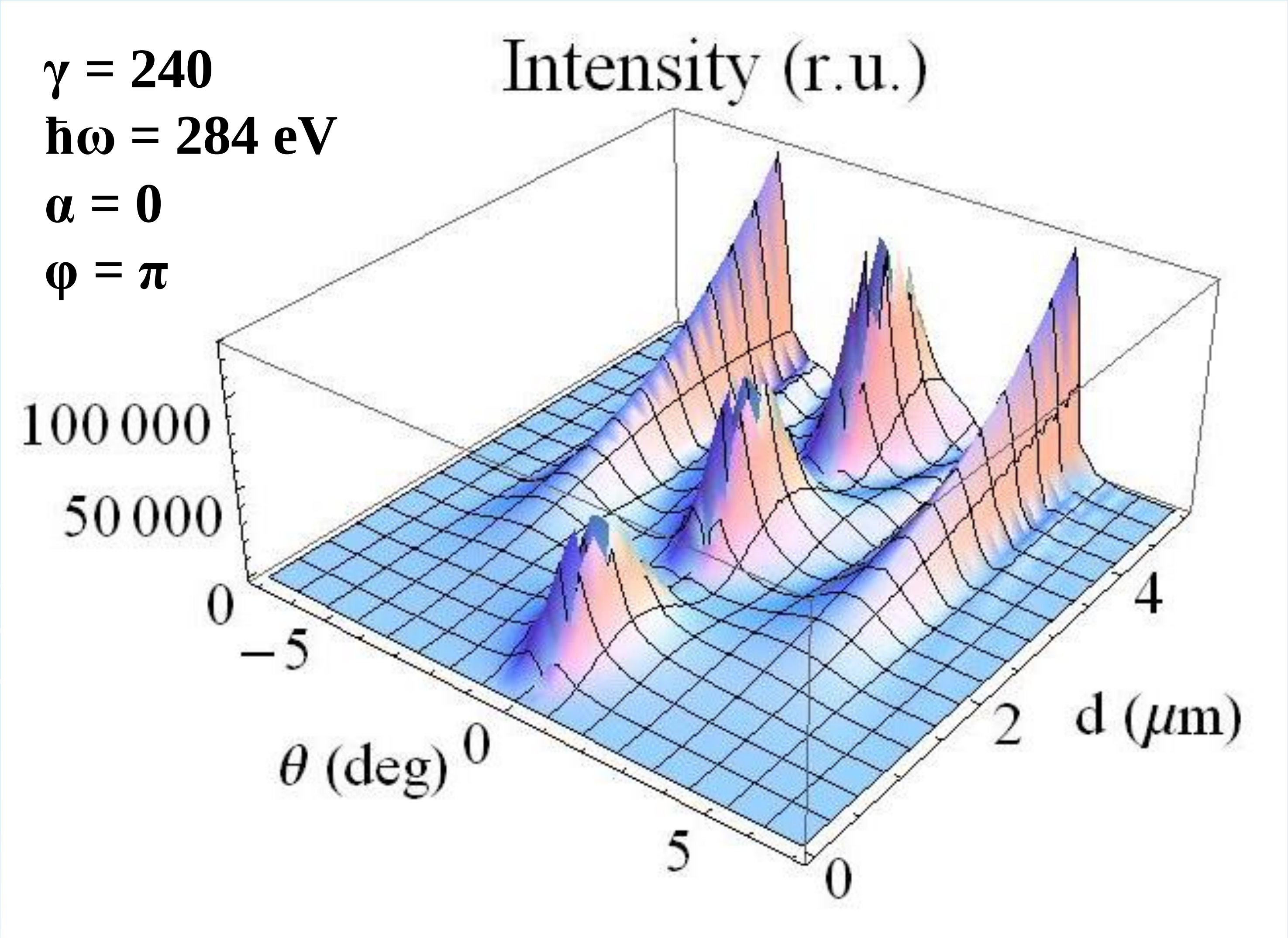
Intensity vs observation angle θ and thickness d



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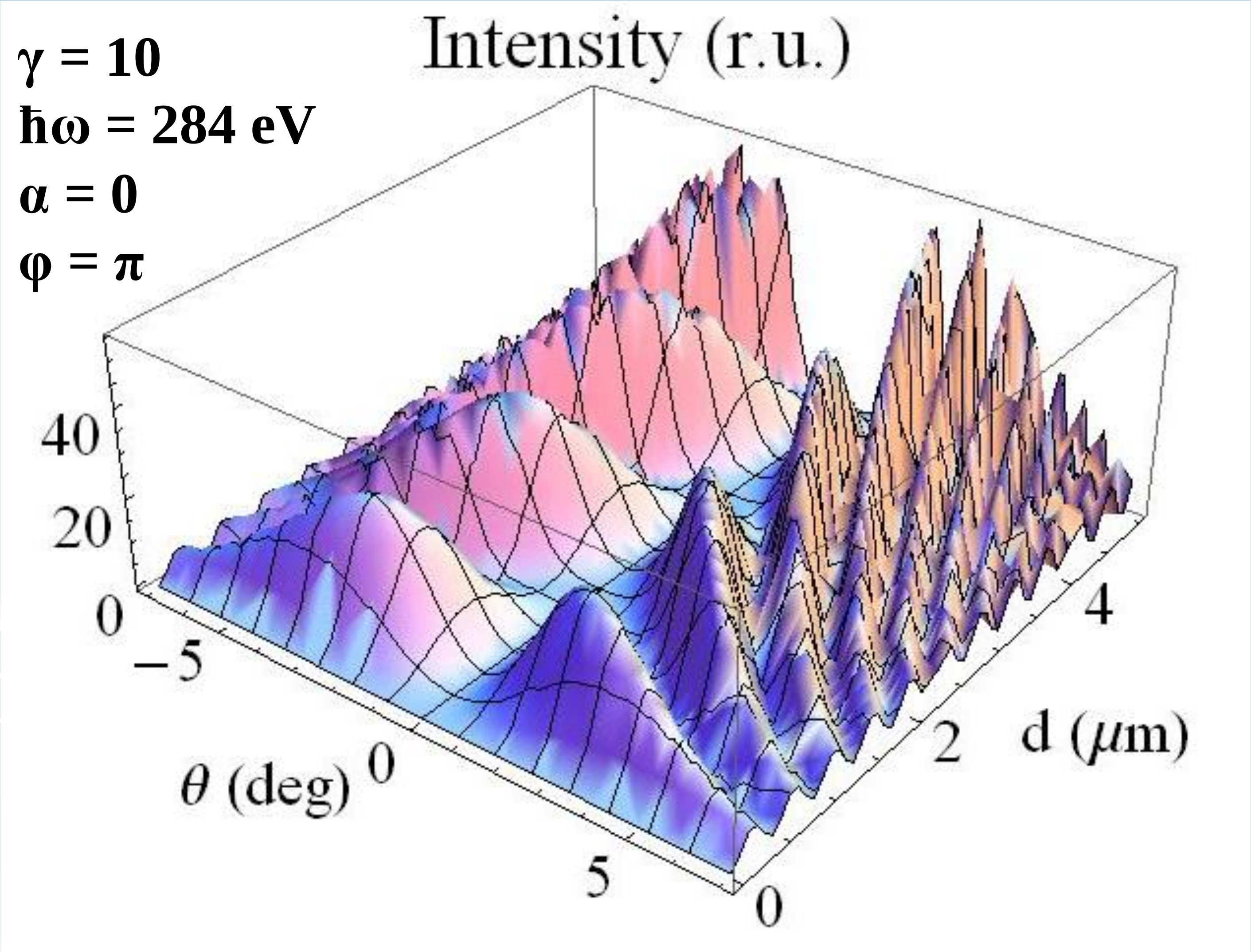
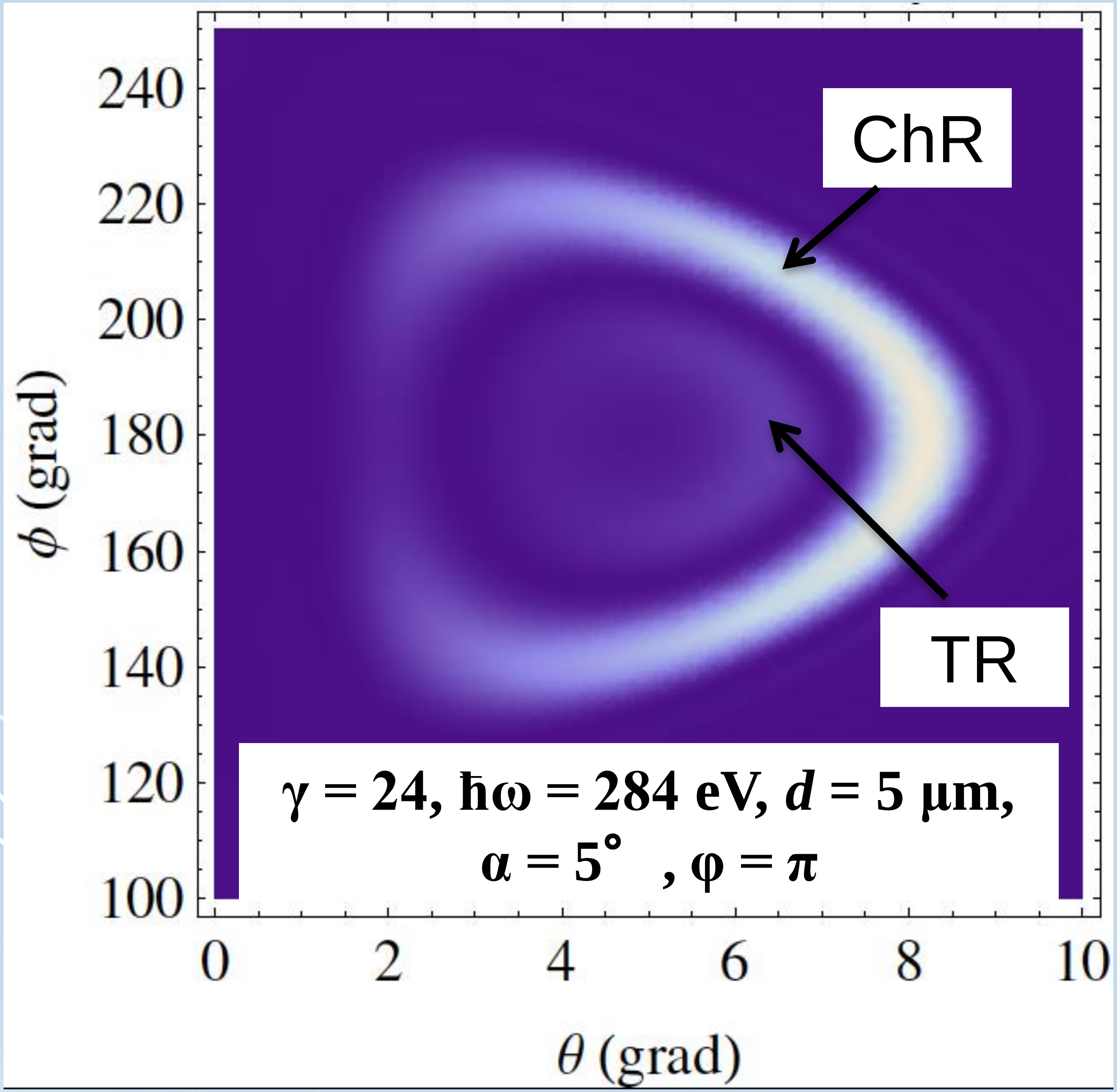


Oblique Incidence



X-Ray Cherenkov Diffraction Radiation

Intensity vs observation angle θ and thickness d

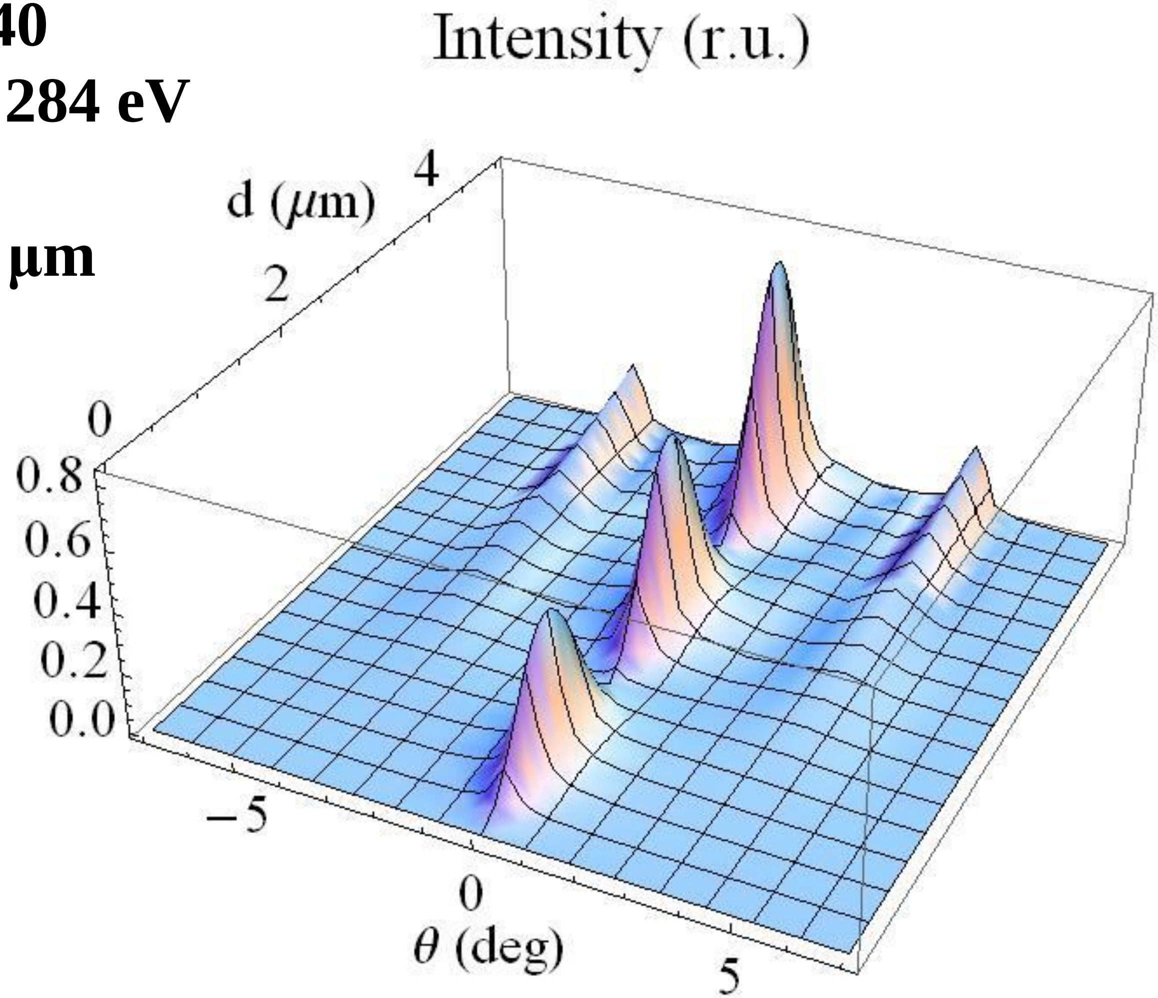
$\gamma = 240$

$\hbar\omega = 284$ eV

$\alpha = 0$

$h = 1$ µm

$\varphi = \pi$



Intensity vs observation angle θ and thickness d

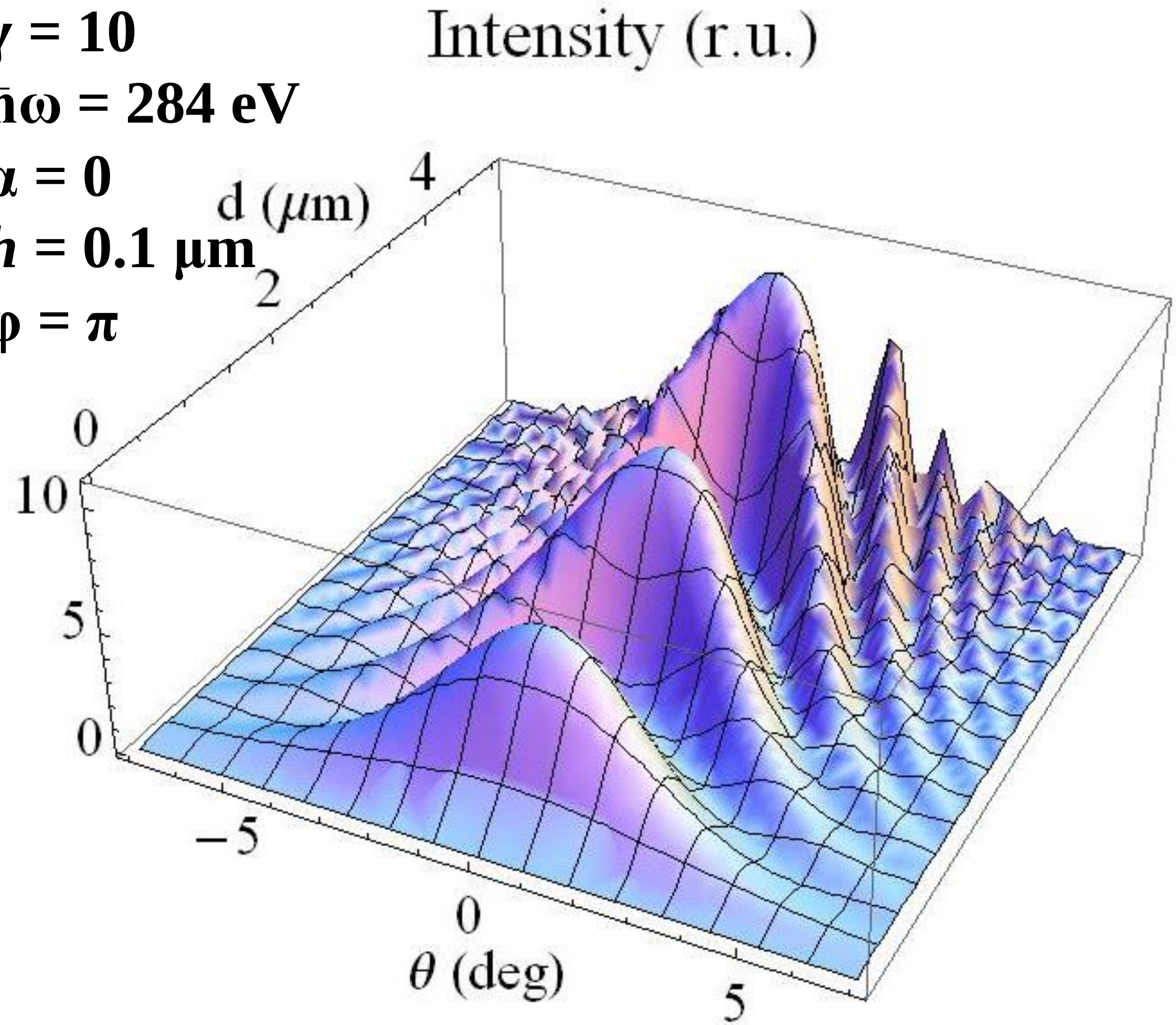
$\gamma = 10$

$\hbar\omega = 284$ eV

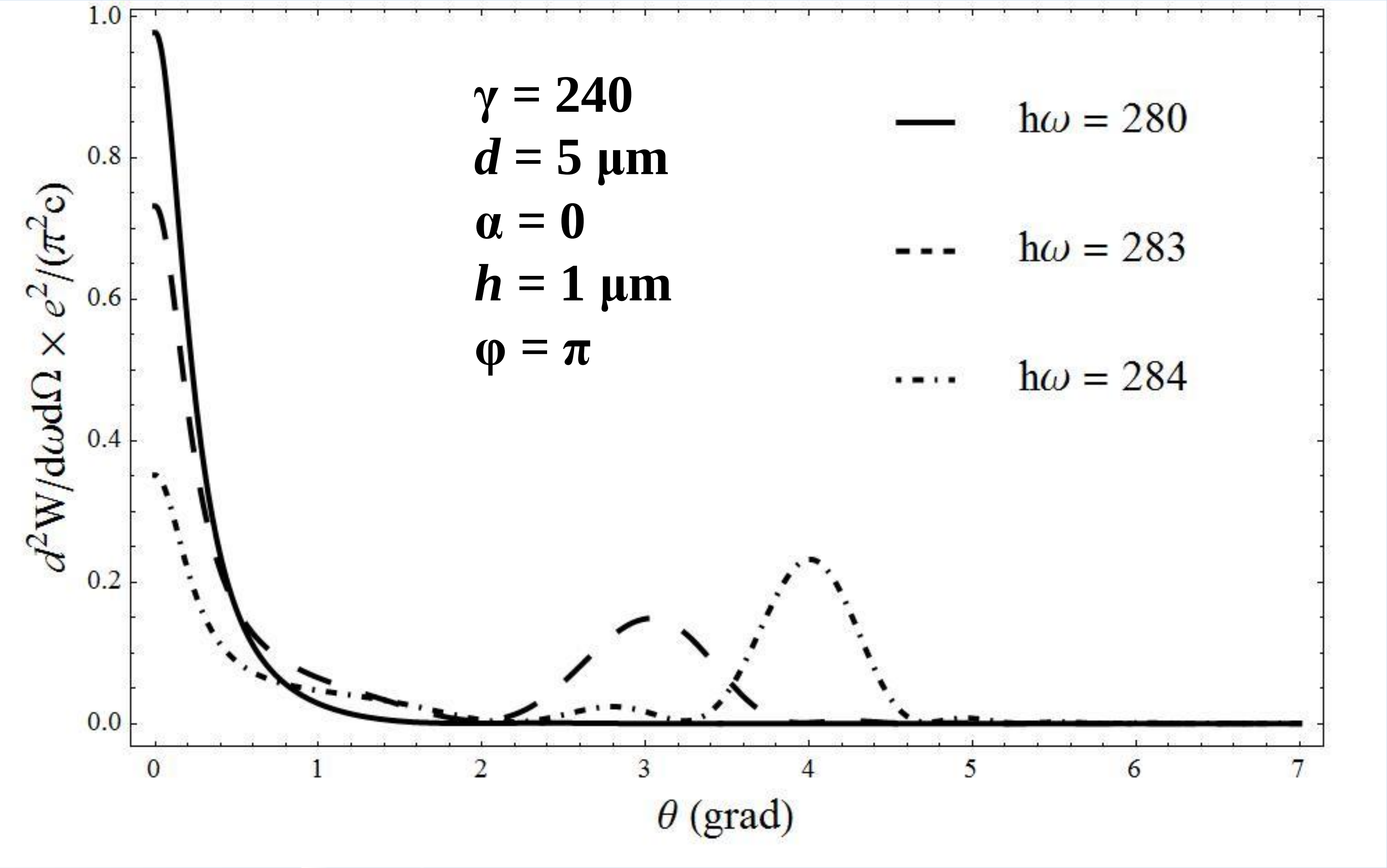
$\alpha = 0$

$h = 0.1$ μm

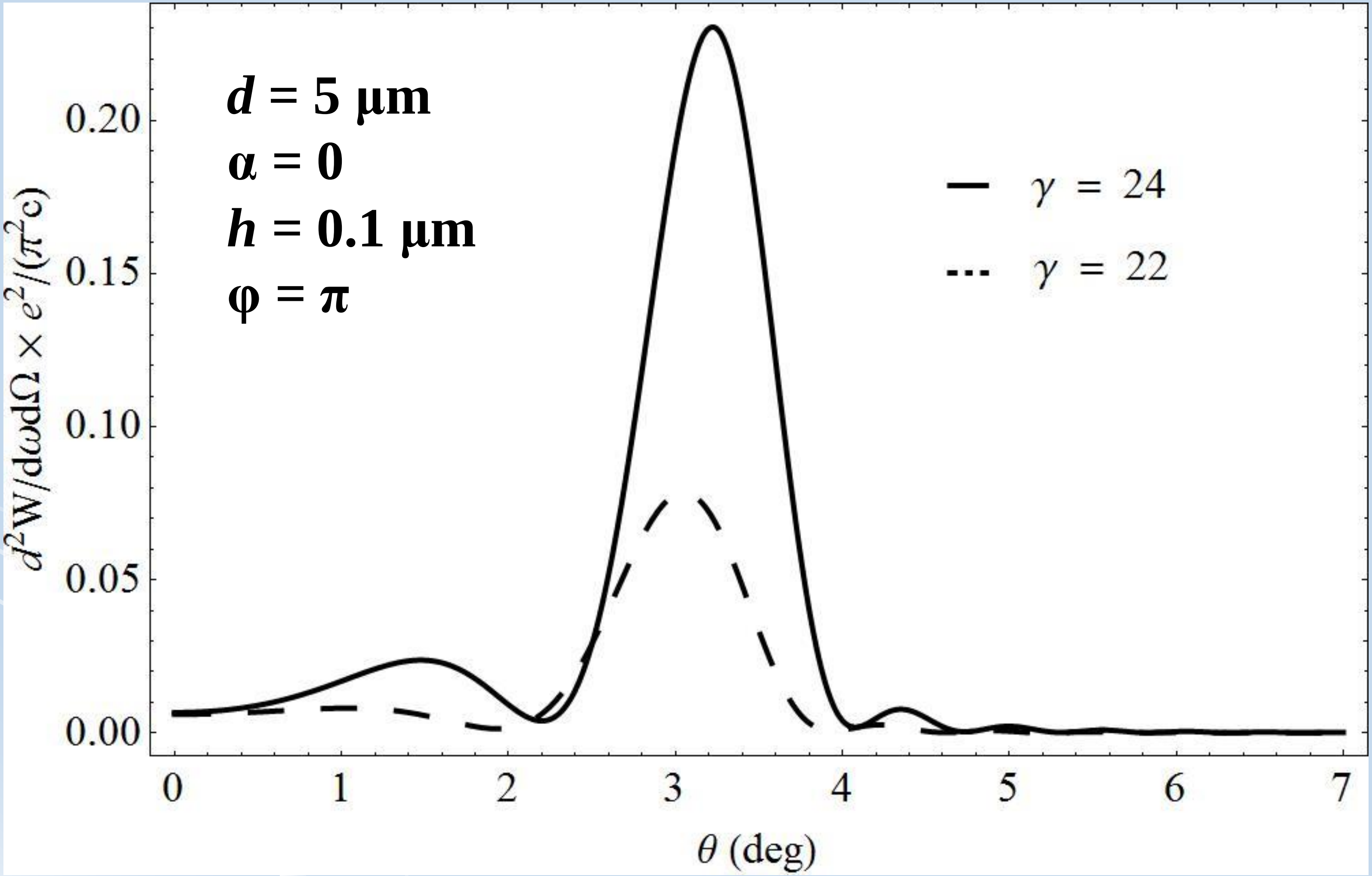
$\varphi = \pi$



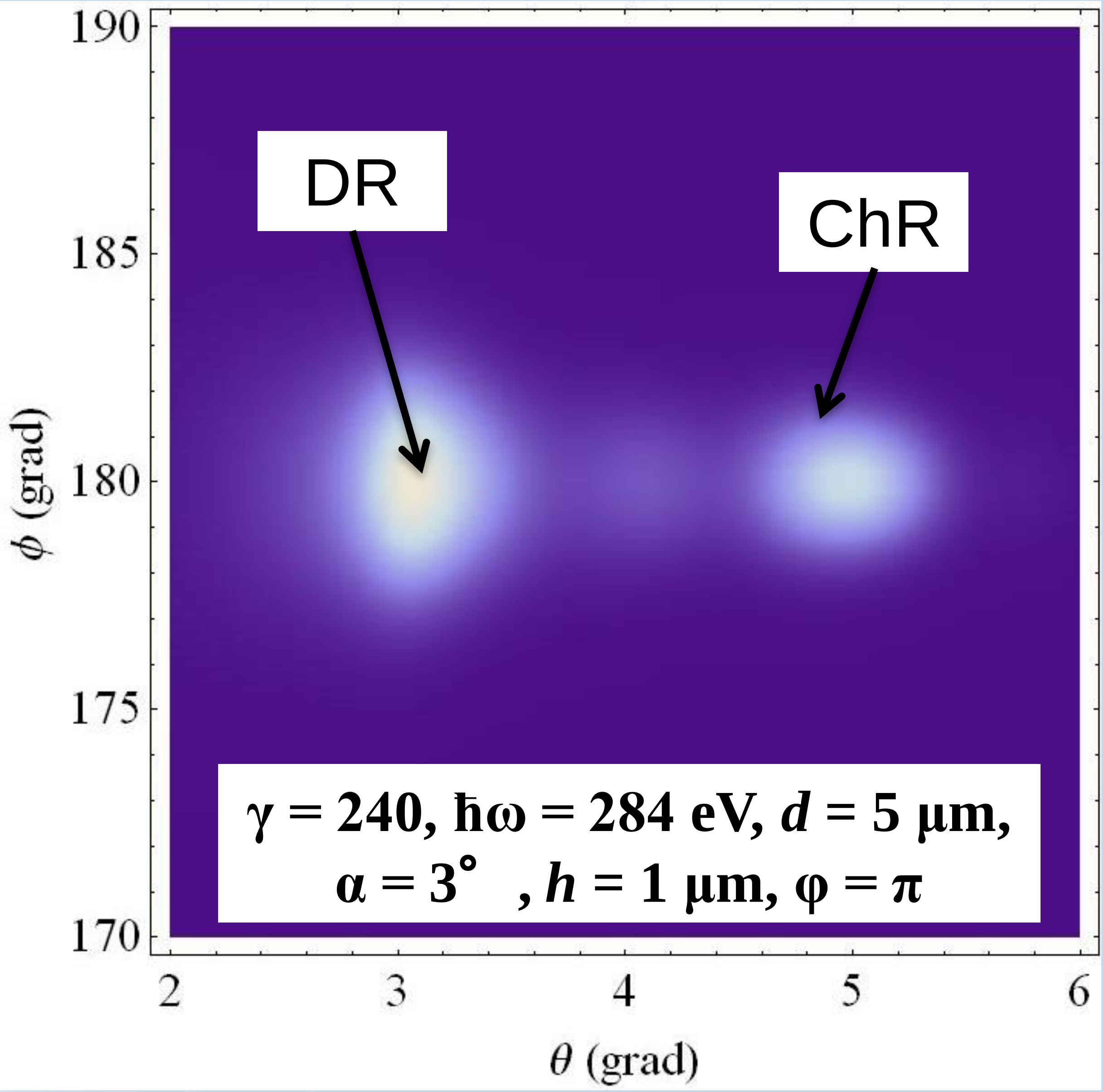
Intensity vs observation angle θ for different photon energies



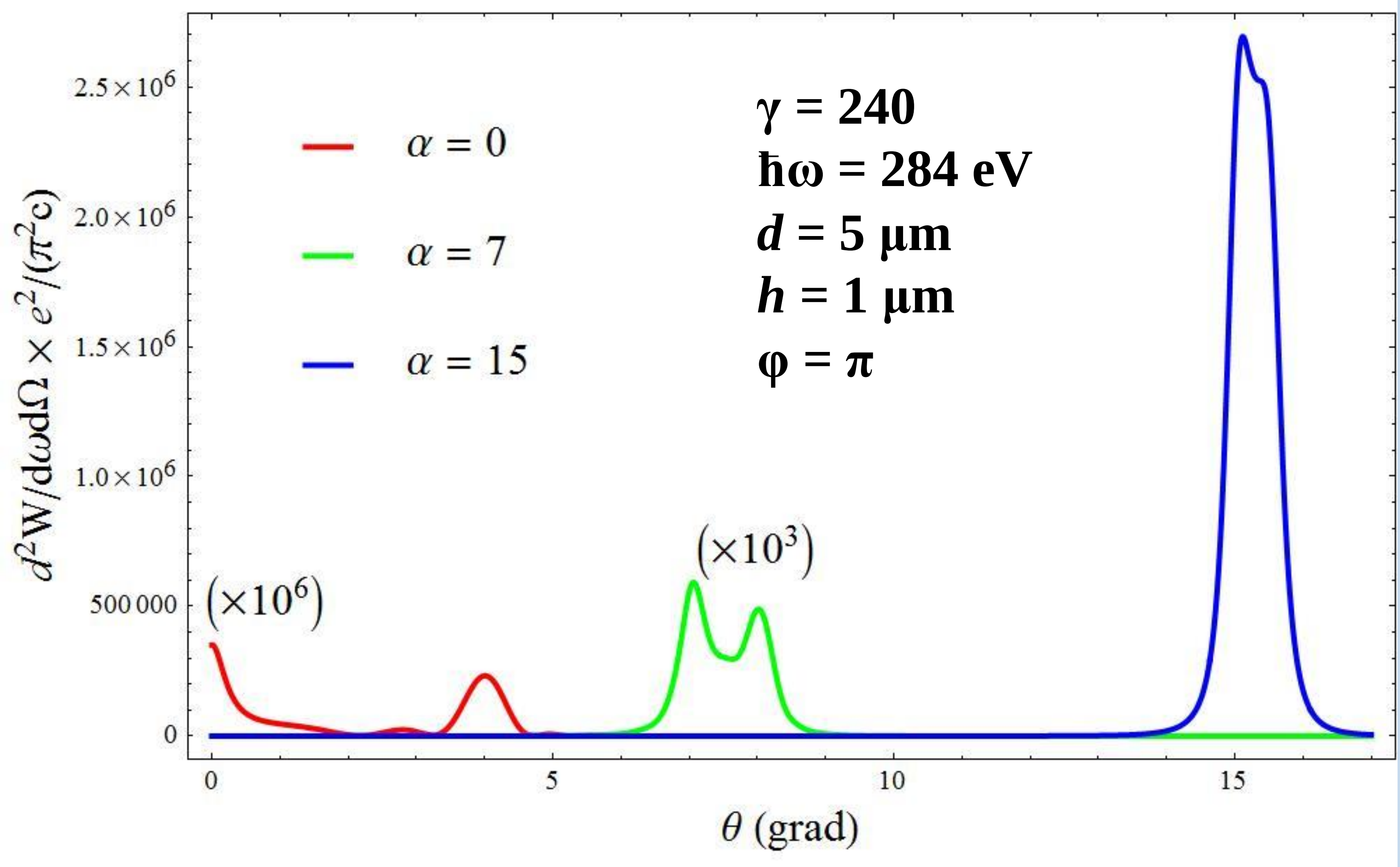
Intensity vs observation angle θ for different electron energies



Oblique Incidence



Intensity vs observation angle θ for different incidence angles



Conclusion

- The model based on Polarization Current method agrees with other models for given beam parameters and approximations;

- The Cherenkov Radiation is highly monochromatic in X-ray wavelength range;

- The Angular distribution can be used to measure the beam energy with 10% accuracy;

- In the energy range of $\gamma > 100$ the Polarization Radiation can be used to determine the beam angular divergence;

- A real application for beam diagnostics is yet to be estimated!

Thank you for your attention!