X-RAY TRANSITION RADIATION BY MULTI-GEV ELECTRONS IN A THIN TARGET PLACED IN AN EXTERNAL MAGNETIC FIELD *(THEORETICAL STUDIES)*

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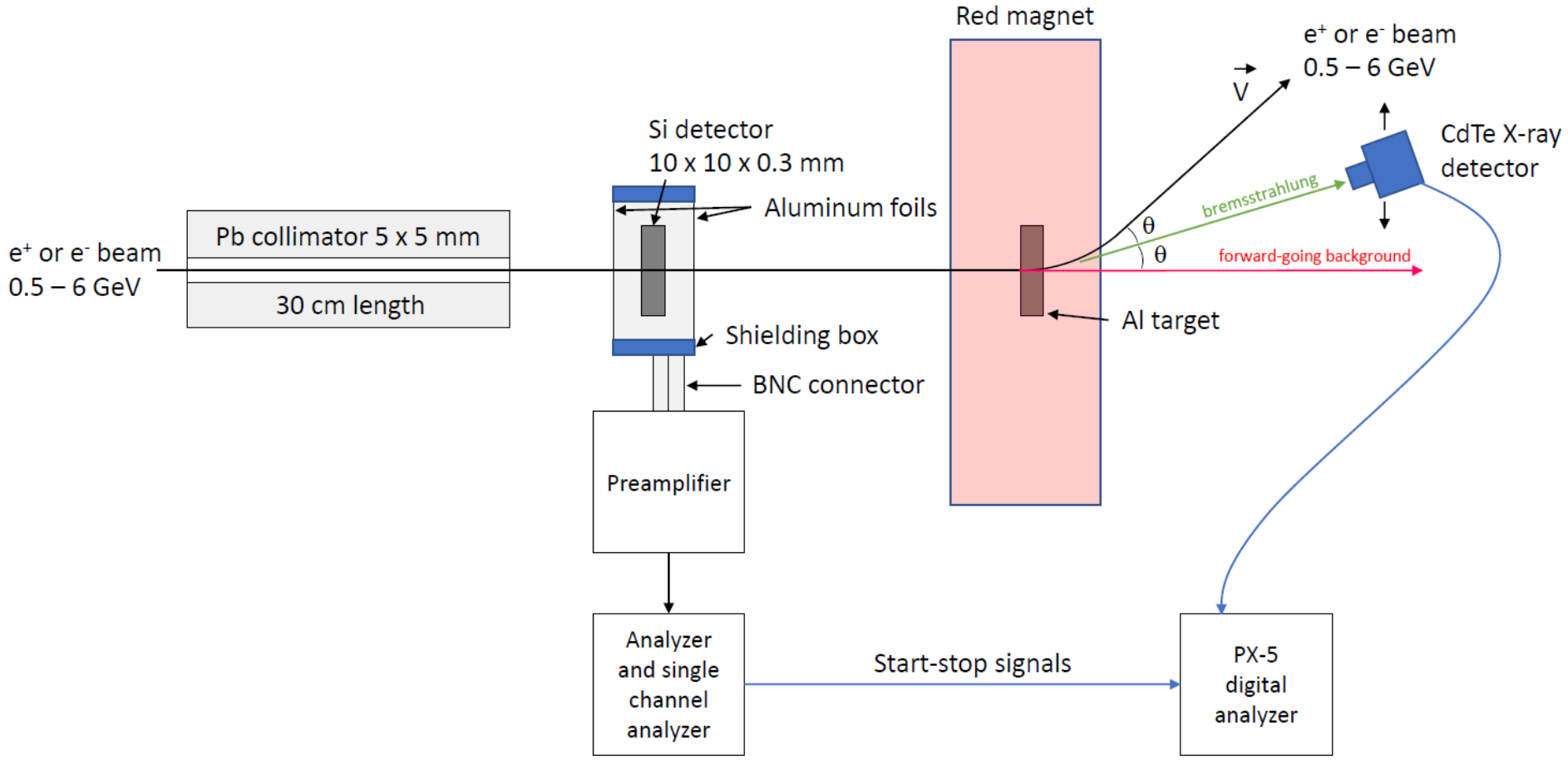
Workshop 'Relativistic Electron Beam Dynamics in Crystals and Related Electrodynamic Processes',

DESY, Hamburg, Germany, 08-10 December, 2025

FIRST MEASUREMENTS (2024)

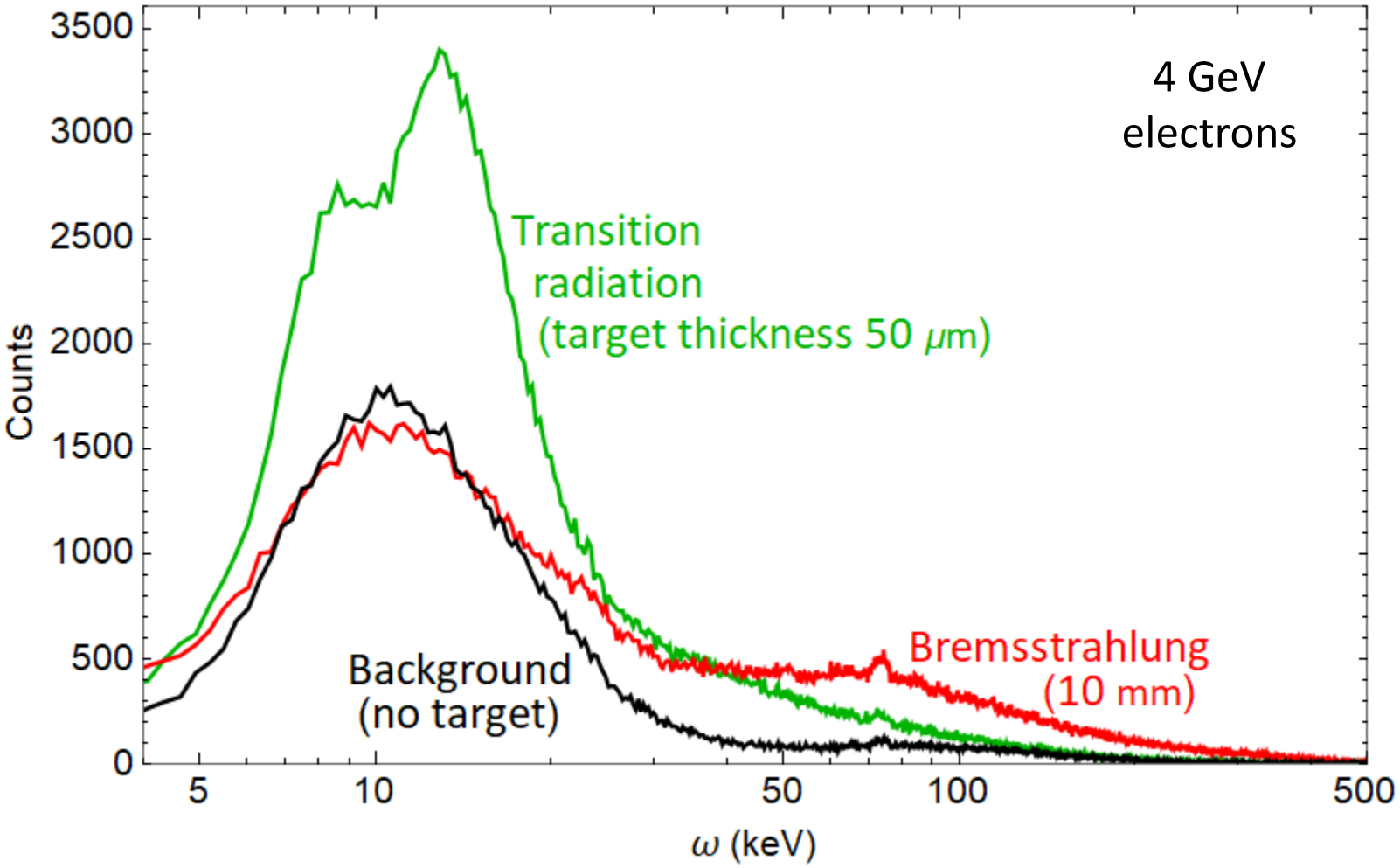
From *A.P. Potylitsyn, G. Kube, A. Novokshonov, A. Shchagin, S. Strokov et al. Report at DESY-KIPT workshop dedicated to the memory of N.F. Shul'ga (2024)*

Experimental setup at Test Beam Facility TB-21 for the studies of dielectric suppression (Ter-Mikaelyan) effect in x-ray bremsstrahlung



FIRST MEASUREMENTS (2024)

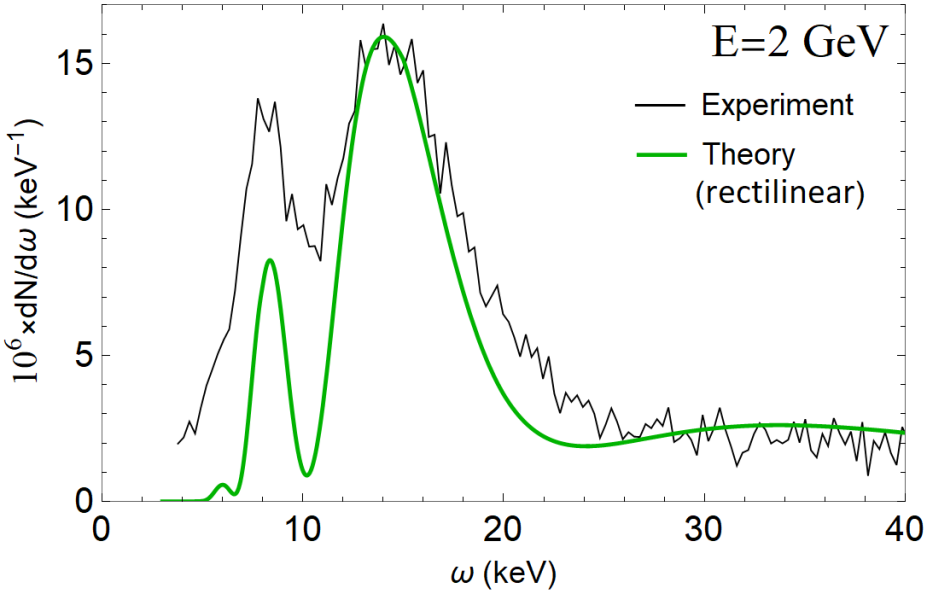
TR, Bremsstrahlung and Background raw spectra:

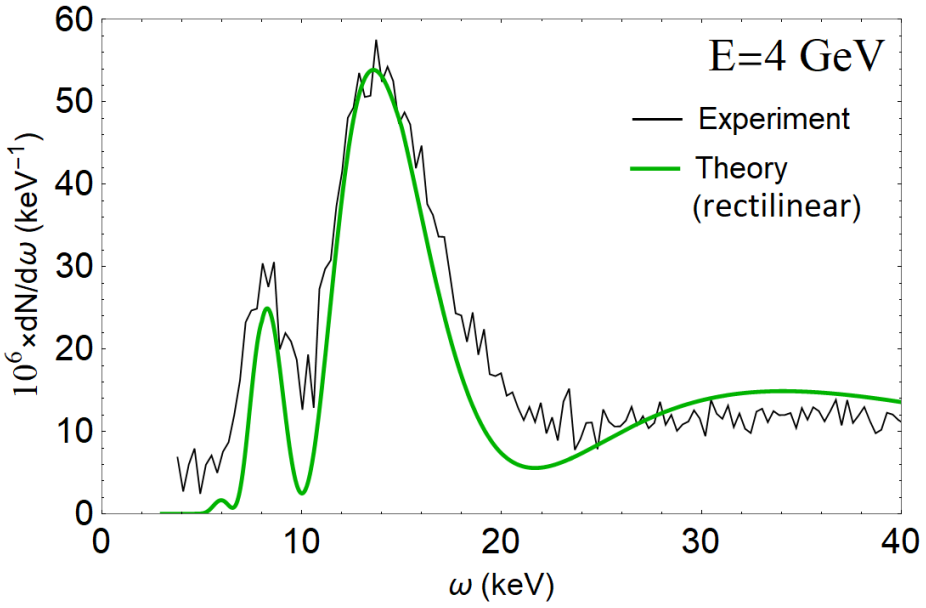


FIRST MEASUREMENTS (2024)

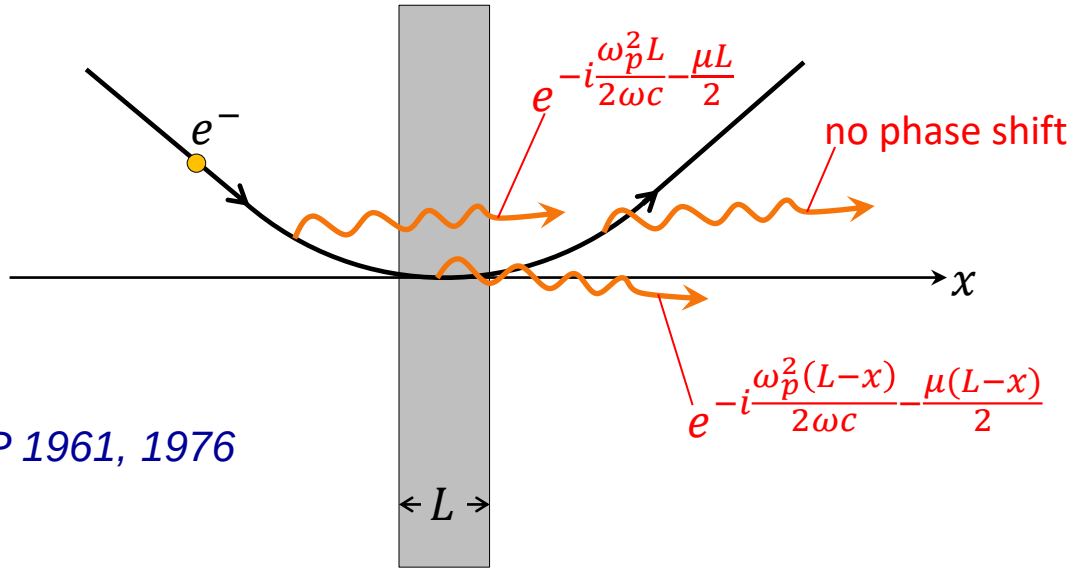
The measurements were performed for 1, 2, 3 and 4 GeV electrons

Measured and calculated TR spectra from 50 μm Al target (calculations on the basis of the theory for rectilinear particle motion):





CALCULATION METHOD FOR A CIRCULAR TRAJECTORY



For optical region:
G.M. Garibyan // JETP 1961, 1976

Spectral-angular density of the photon number:

$$\frac{d^2N}{dod\omega}=\frac{\omega\alpha}{4\pi^2c^2}\left|\int_{-\infty}^{\infty}dt\vec{n}\times\vec{v}(t)e^{i\omega[t-\vec{r}(t)\cdot\vec{n}/c]}e^{i\phi[x(t)]}\right|^2$$

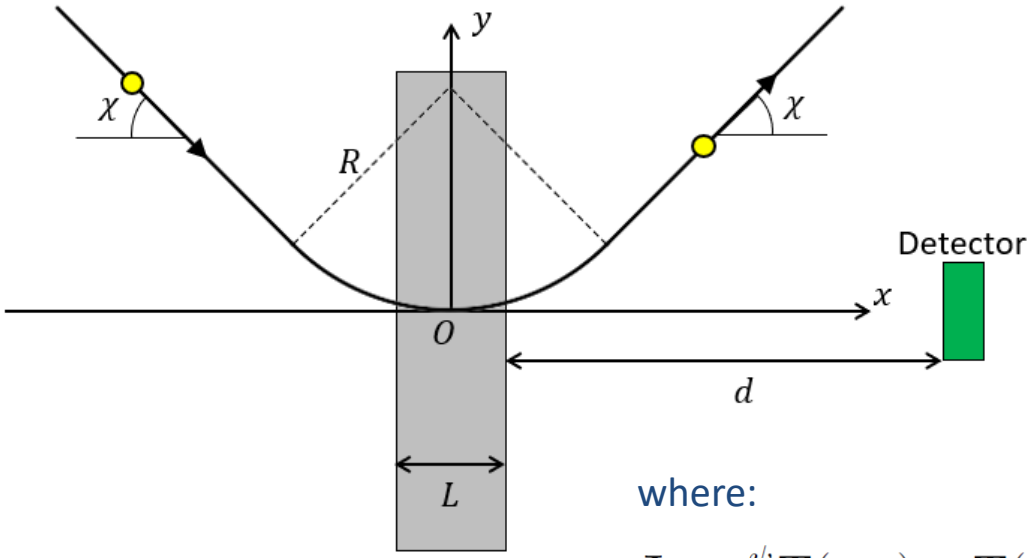
where:

$$\int_{-\infty}^{\infty}dt\vec{n}\times\vec{v}e^{i\omega(t-\vec{r}\cdot\vec{n}/c)}=e^{-i\frac{\omega_p^2 L}{2\omega c}-\frac{\mu L}{2}}\int_{-\infty}^{0}dt\vec{n}\times\vec{v}e^{i\omega(t-\vec{r}\cdot\vec{n}/c)}$$

$$+\int_{0}^{L/v}dt\vec{n}\times\vec{v}e^{i\omega(t-\vec{r}\cdot\vec{n}/c)}e^{-i\frac{\omega_p^2[L-x(t)]}{2\omega c}-\frac{\mu[L-x(t)]}{2}}$$

$$+\int_{L/v}^{\infty}dt\vec{n}\times\vec{v}e^{i\omega(t-\vec{r}\cdot\vec{n}/c)}$$

TR SPECTRAL-ANGULAR DENSITY



Spectral-angular density of the photon number:

$$\frac{d^2N}{dod\omega} = e^{-\mu_a d}\frac{\alpha}{4\pi^2\omega}|\mathbf{J}|^2$$

where:

$$\mathbf{J} = e^{\psi}\mathbf{T}(-\chi) - \mathbf{T}(\chi) + e^{\psi}\mathbf{F}(-\chi, -L/2R) + \mathbf{F}(L/2R, \chi)$$
$$+\frac{R\omega}{c}\int_{-L/2R}^{L/2R} da\mathbf{X}(a)\exp\left[\frac{i\omega R}{v}g(a) - \frac{R\psi\sin a}{L} + \frac{\psi}{2}\right]$$

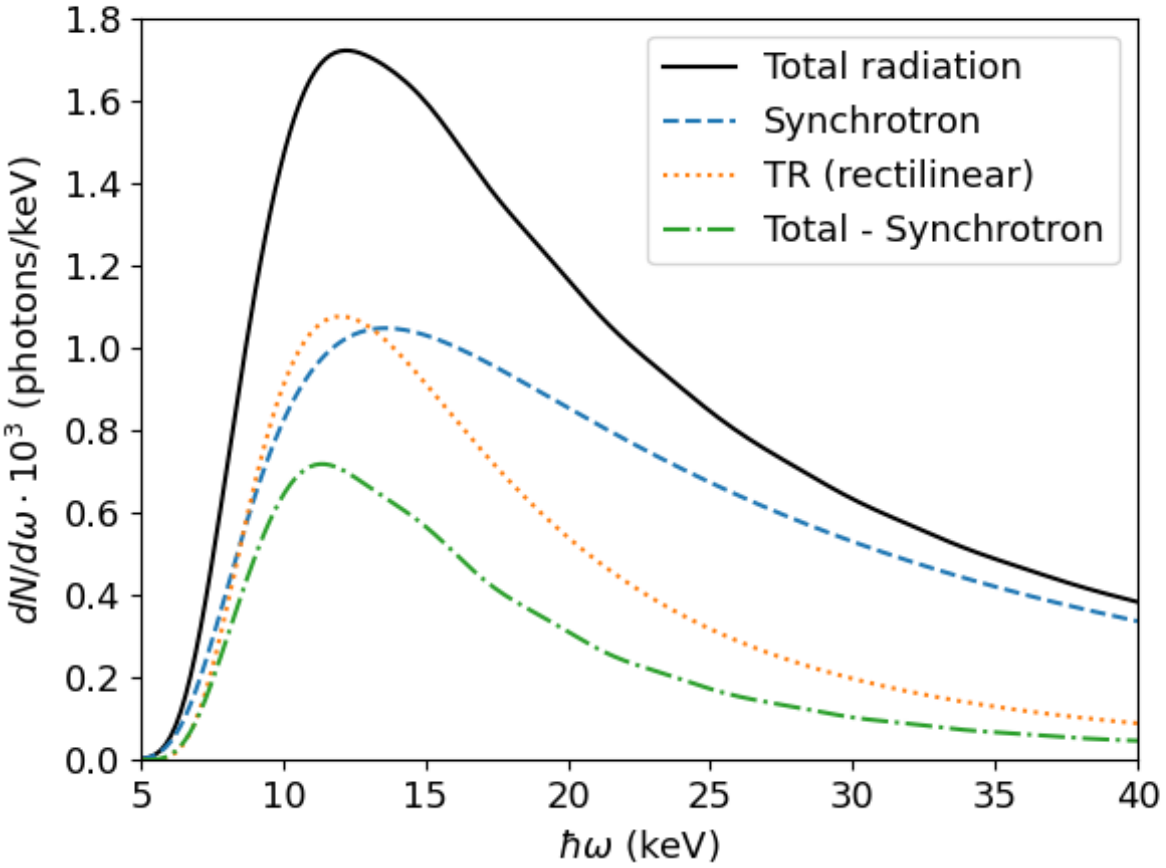
and:

$$\psi = -\mu L/2 - i\omega_p^2 L/2\omega c,$$
$$g(a) = a - \beta\sin a\cos\vartheta - \beta(1-\cos a)\sin\vartheta\cos\phi,$$
$$\mathbf{X}(a) = \mathbf{e}_y\vartheta\sin\phi + \mathbf{e}_z(a - \vartheta\cos\phi),$$
$$\mathbf{F}(a,b) = \frac{\omega R}{c}\int_a^b dx\mathbf{X}(x)\exp\left[i\omega Rg(x)/v\right],$$
$$\mathbf{T}(\chi) = -2i\mathbf{X}(\chi)\exp\left[i\omega Rg(\chi)/v\right]/Q(\chi).$$
$$Q(\chi) = \gamma^{-2} + \vartheta^2 + \chi^2 - 2\chi\vartheta\cos\phi$$

RADIATION SPECTRA IN THE DETECTOR

electron energy: $E = 6$ GeV
target thickness: $L = 12\ \mu$m
detector acceptance: $\theta_0 = 1$ mrad

trajectory radius: $R = 13.34$ m
distance to the detector: $d = 1.5$ m

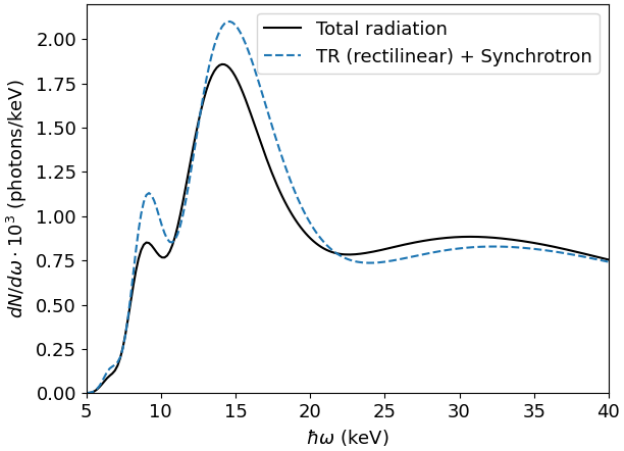


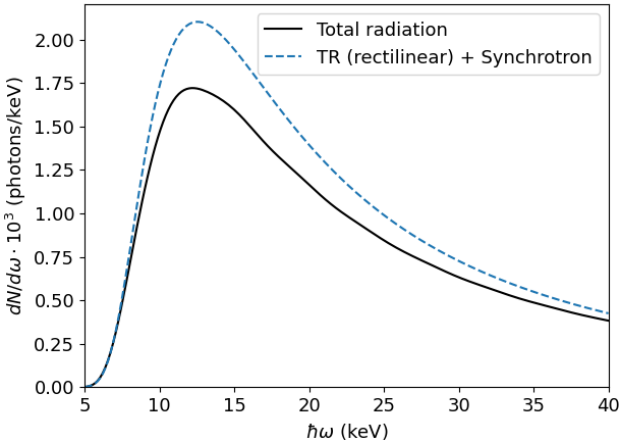
Green line is lower than the orange line → destructive interference between TR and synchrotron radiation

$L = 50\ \mu m$

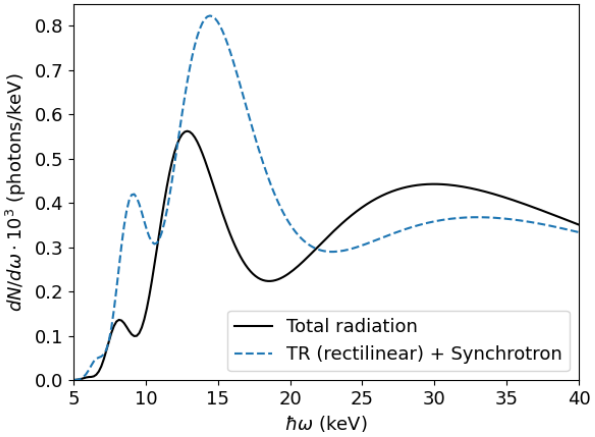
$L = 12\ \mu m$

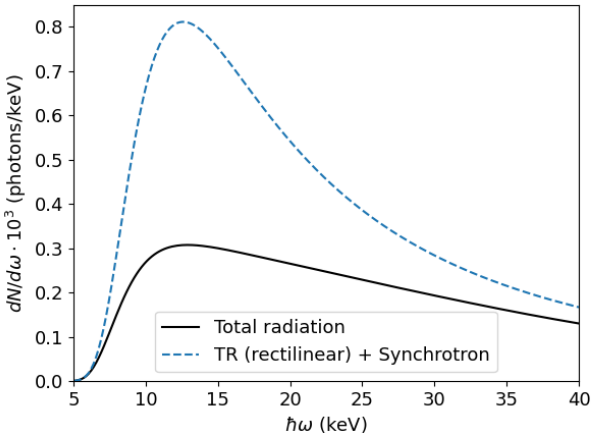
$E = 6$ GeV
$\theta_0 = 1$ mrad



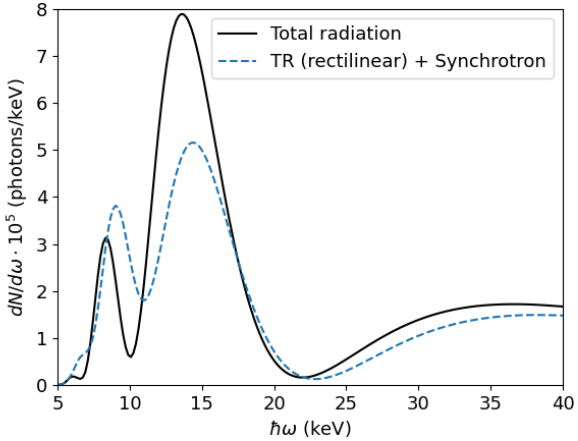


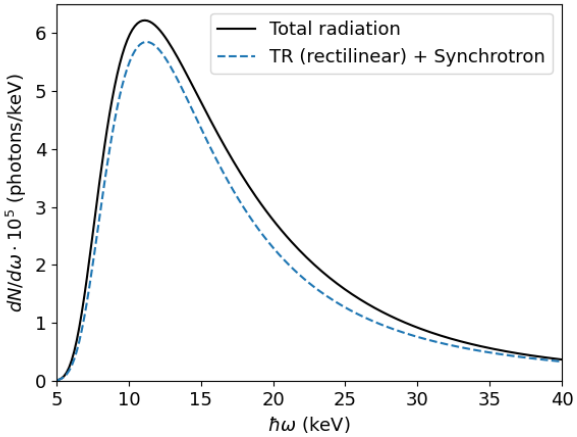
$E = 6$ GeV
$\theta_0 = 0.4$ mrad





$E = 2$ GeV
$\theta_0 = 0.4$ mrad





DEPENDENCE OF THE RATIO $\eta = N/(N_{TR} + N_{SR})$ ON THE ACCEPTANCE ANGLE θ_0

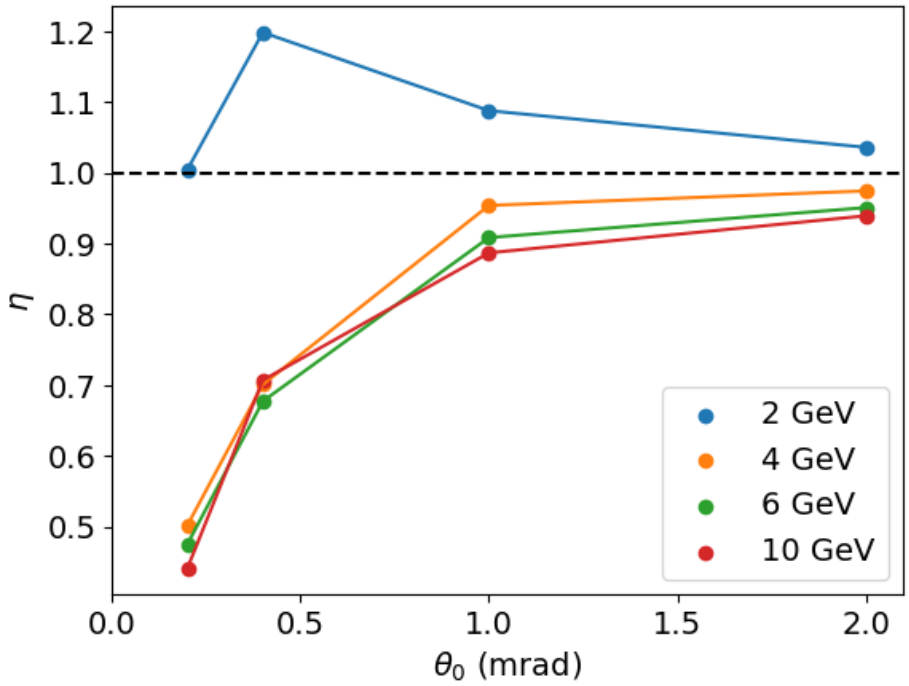
N – total radiation photon number

N_{TR} – TR photon number for rectilinear trajectory

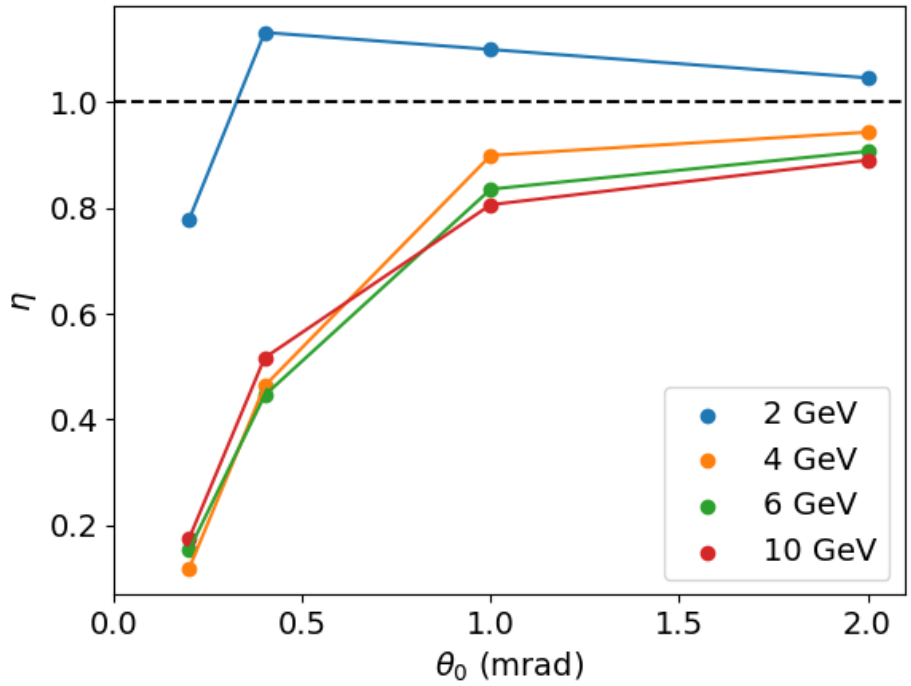
N_{SR} – synchrotron radiation photon number (no target)

Spectra integrated in the region $5\ \text{keV} < \omega < 25\ \text{keV}$

$L = 50\ \mu m$

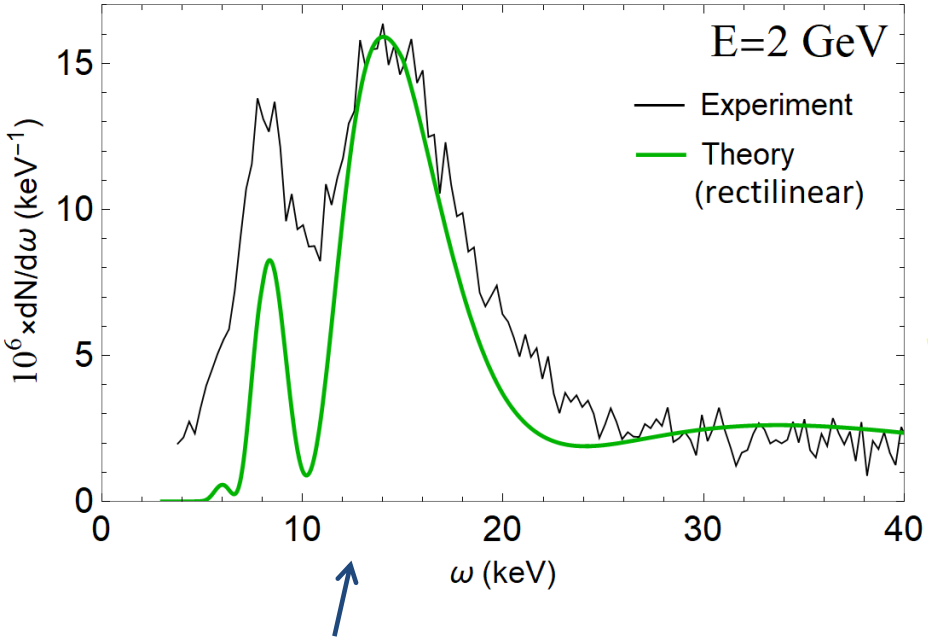


$L = 12\ \mu m$



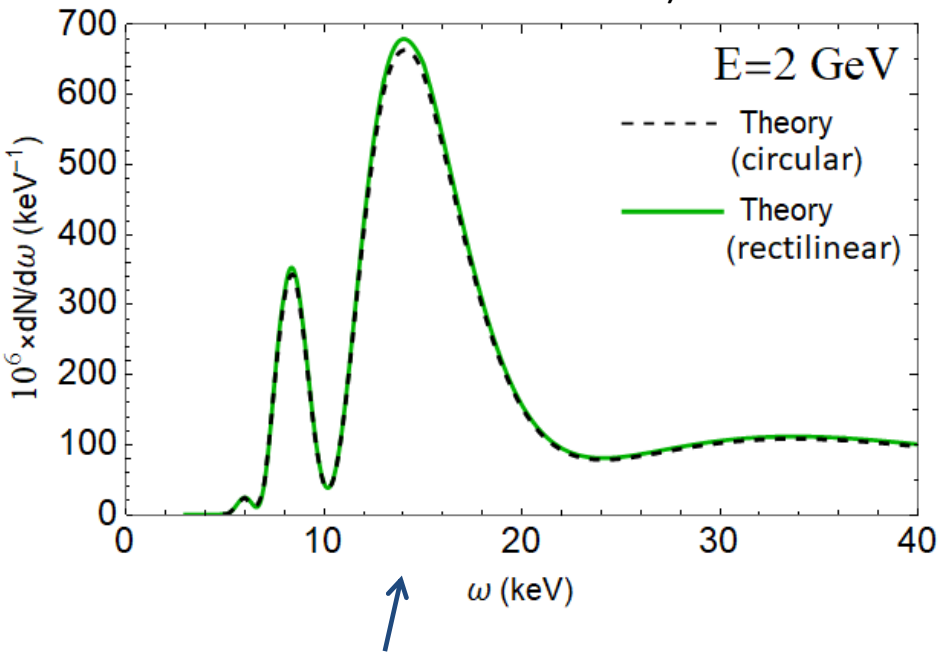
POSSIBLE REASON FOR DEVIATION FROM THE MEASUREMENTS

Measured and calculated spectra (calculation for rectilinear motion, as in slide 4):



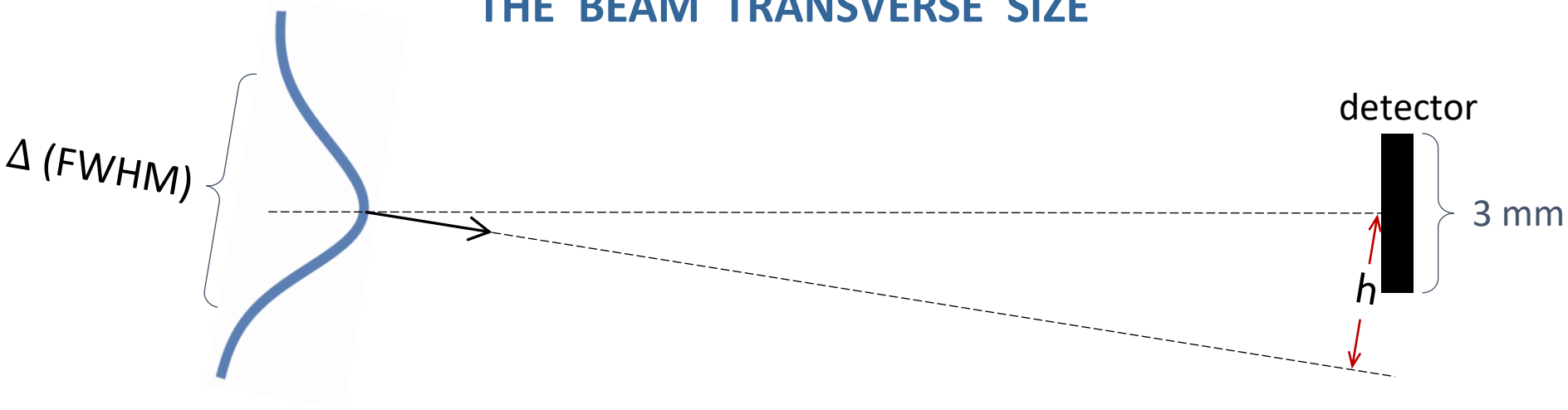
normalization to the height of the experimental spectrum

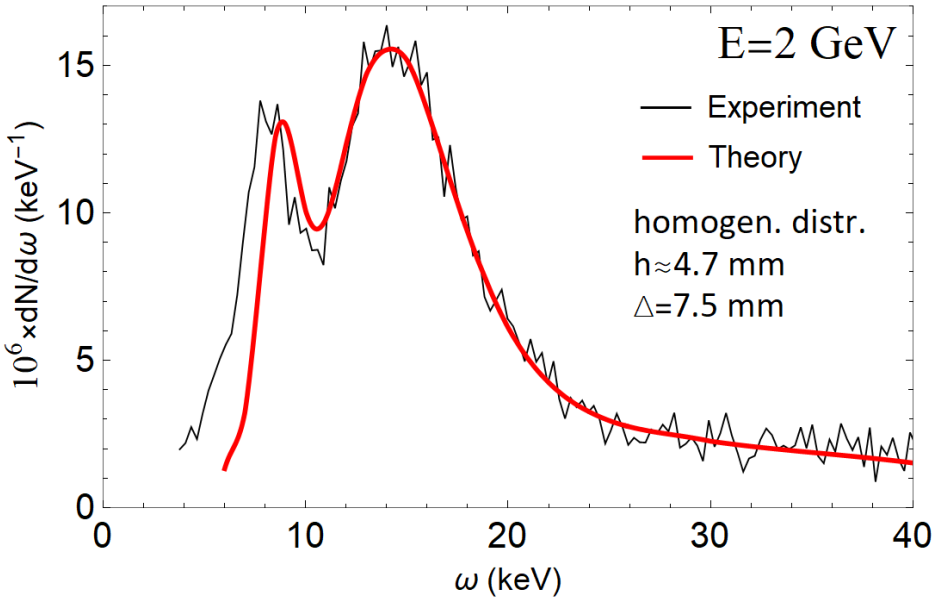
Calculated spectra (for rectilinear and circular motion):

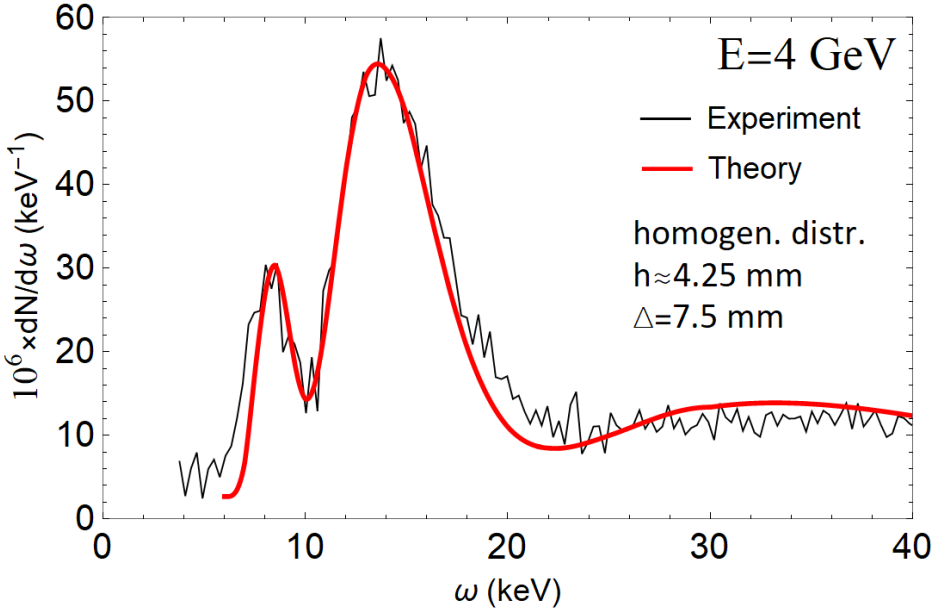


absolute values

TAKING INTO ACCOUNT POSSIBLE SHIFT OF THE BEAM DIRECTION AND THE BEAM TRANSVERSE SIZE







CONCLUSIONS

- X-ray radiation by 2–10 GeV electrons in a thin target placed in a strong magnetic field is investigated
- Due to interference effects, the total emission can differ significantly from the simple sum of transition and synchrotron radiation
- Both constructive and destructive interference is possible
- The magnitude of interference effects as a function of electron energy and detector acceptance angle is investigated

I. V. Demydenko, S. V. Trofymenko, A. P. Potylitsyn, G. Kube, A. V. Shchagin, X-ray transition radiation by high-energy electrons in a thin solid target placed in external magnetic field. *Phys. Rev. Accel. Beams* (in press)