Photons from Coherent Bremsstrahlung

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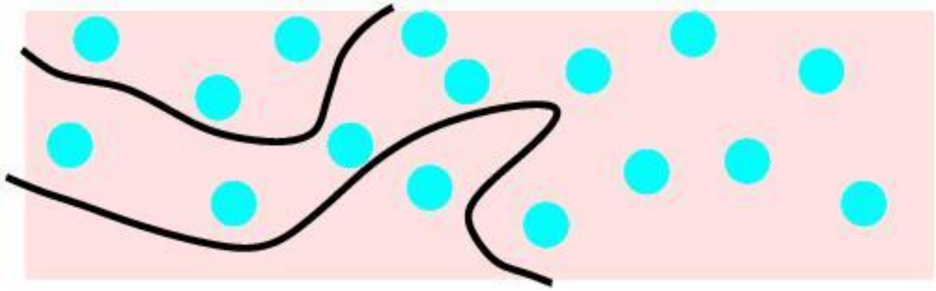
Outline

- **Coherent Radiation Process in oriented crystal**
- **Peculiarities of Coherent Bremsstrahlung**
- **Summary**

Coherent Effects in Oriented Crystals

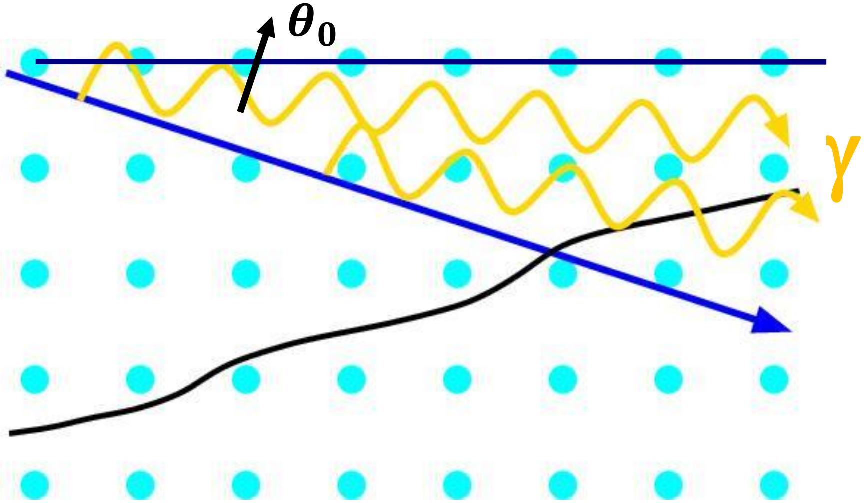
Amorphous Material



Atoms are distributed randomly in amorphous medium. Particles traversing the amorphous material scatter on the potential fluctuation of individual atoms and radiate photons

$$\mathbf{E_1 - E_2 - \omega = 0}$$

$$\vec{\mathbf{p}}_1 - \vec{\mathbf{p}}_2 - \omega\hat{\mathbf{n}} = \vec{\mathbf{q}}$$



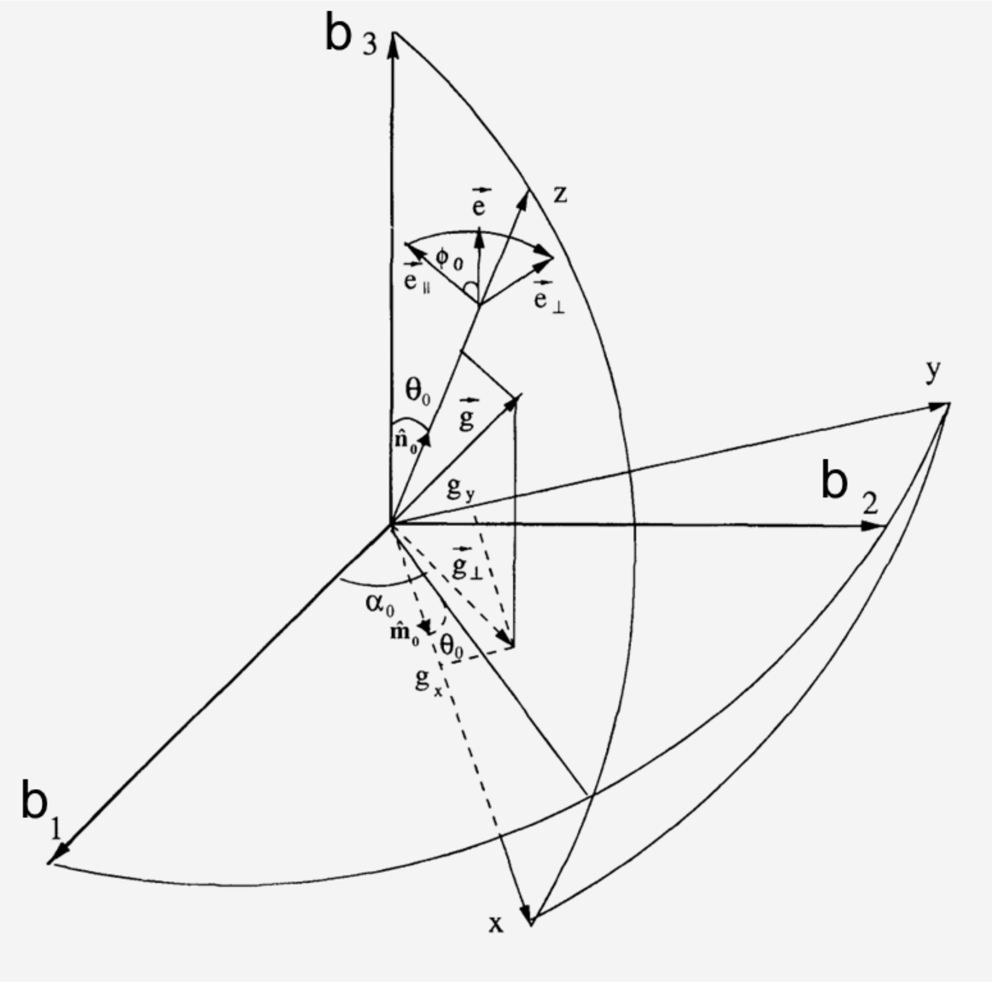
Crystal Lattice

Momentum transfer to the radiator material tends to be very small. Radiator will not change state, and coherent radiation from a crystal becomes possible. For example, for electron energy E =20 GeV and photon energy ω = 10 GeV, q_{min}=6 eV/c.

$$\ell_{coh} = \frac{1}{q_{min}} = \frac{2E_1E_2}{\omega m}\lambda\!\!\!^{-}_c$$

Coherent Length

Crystal orientation with respect to the incoming particles



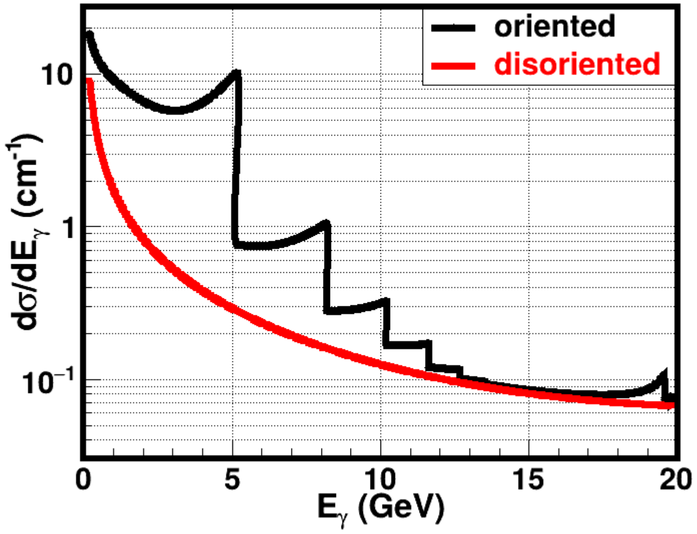
θ_0 - angle between particle momentum and crystal axis b_3, in order of *mrad* or μrad
α_0 – angle between the planes (p,b_3) and (b_1,b_3)

$\psi = \theta_0 \sin \alpha_0$ for $\theta_0 << 1$
Angle between particle momentum p and crystal plane (b1,b3)

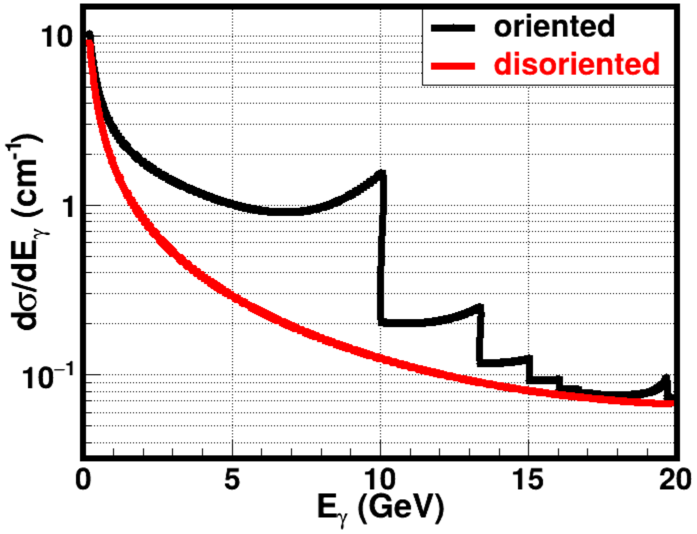
CB Cross Section in Oriented Diamond Single Crystal

Electron beam energy 20 GeV
Operating orientation:
$\theta_0 = 40$ mrad wrt the <100> Axis and ψ is the angle wrt to the (110) plane.

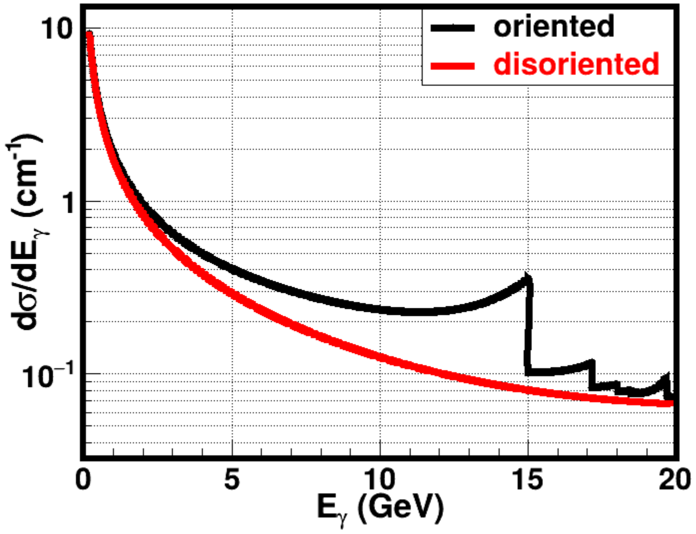
$\psi = 0.3\ mrad$



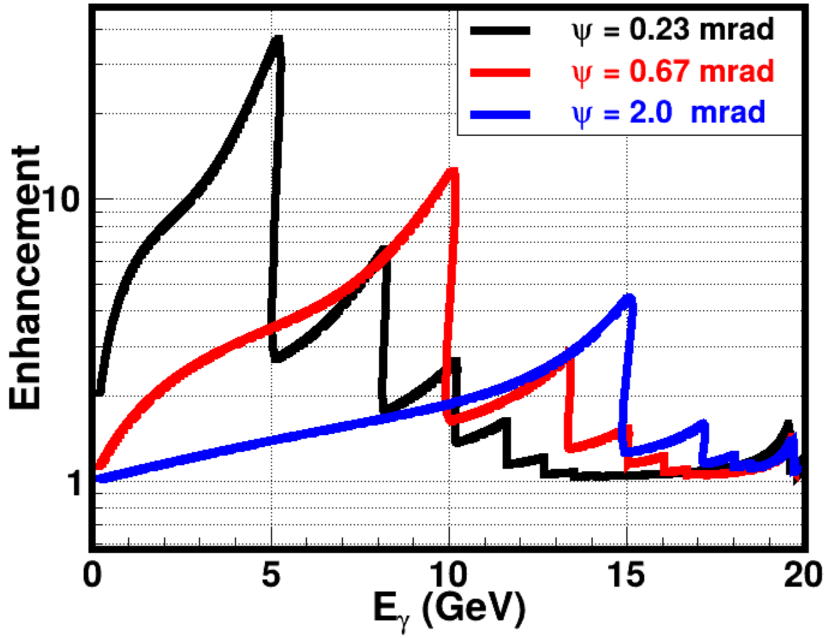
$\psi = 0.67\ mrad$

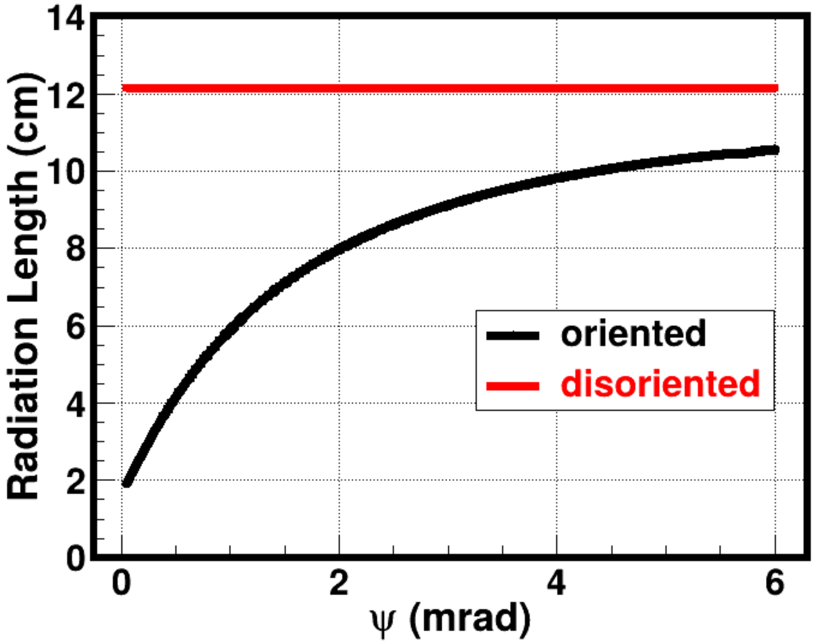


$\psi = 2.0\ mrad$



Enhancement and Radiation Length of Oriented Diamond Single Crystal



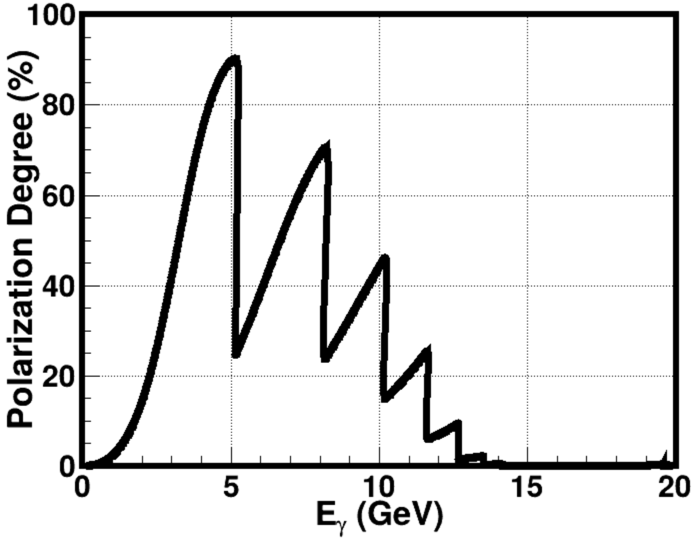


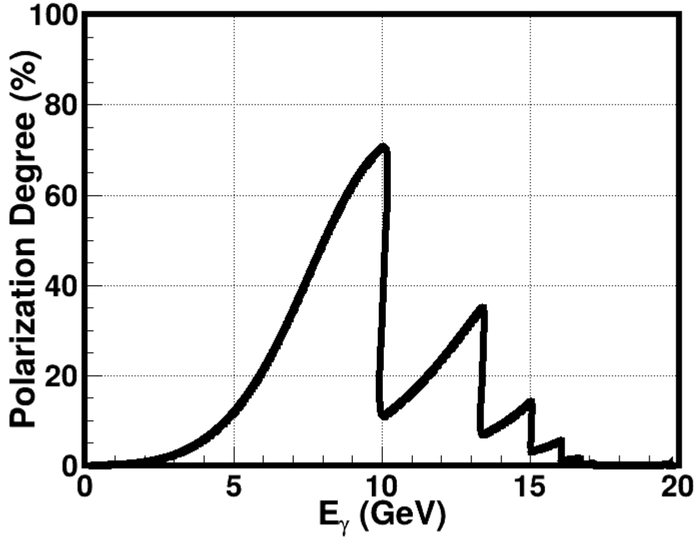
The increase in the CB radiation intensity spectrum is usually reported with respect to the incoherent bremsstrahlung spectrum. This ratio, called the enhancement

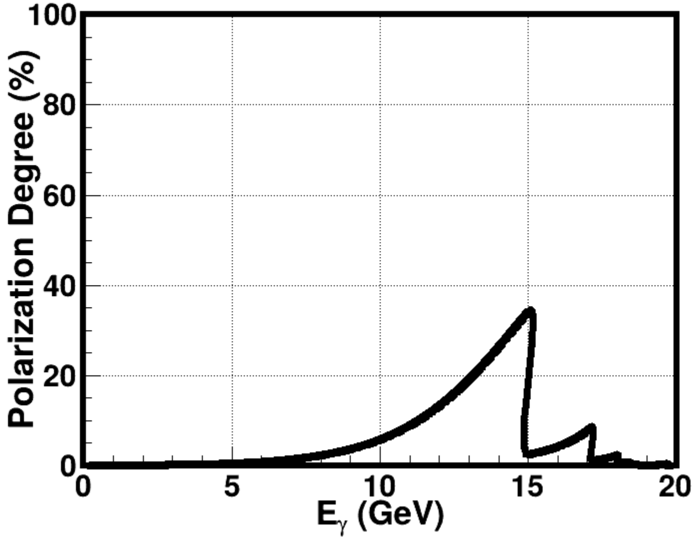
In case of oriented crystal the radiation length depends on the crystal orientation.

Polarization of the Photons Produced by Coherent Bremsstrahlung

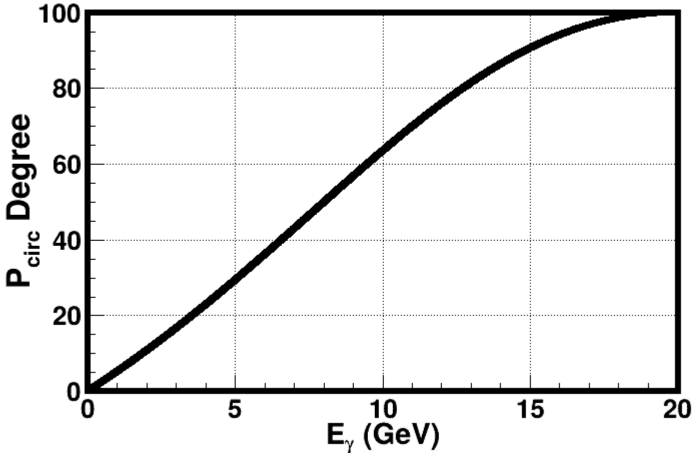
Linear Polarization







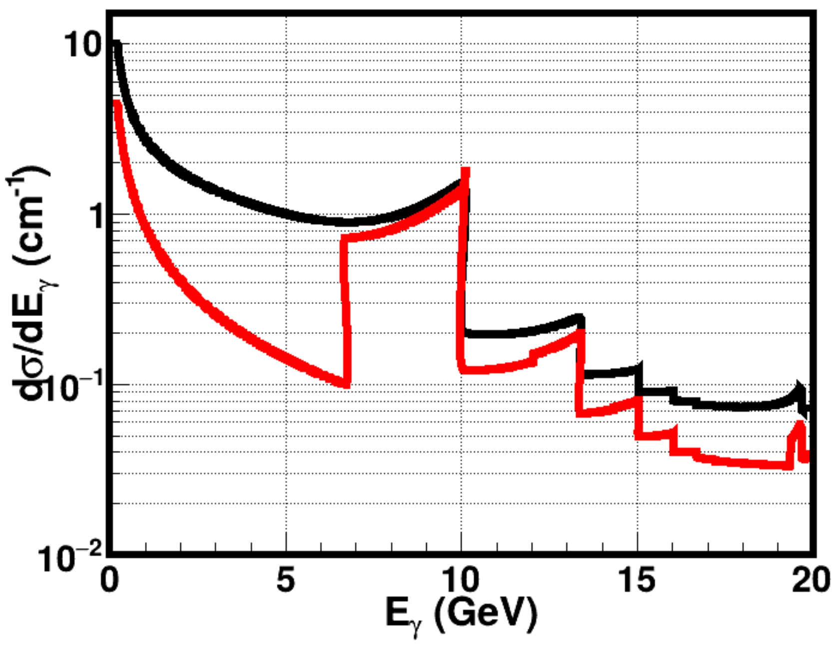
Circular Polarization

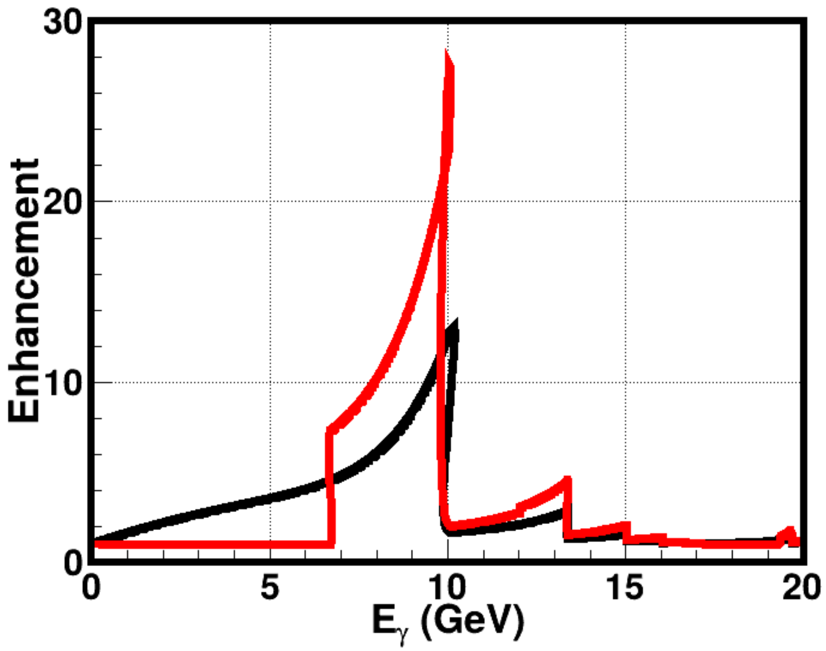


CB of unpolarized electrons in aligned single crystals produces linearly polarized photons.

If the initial electron beam is longitudinally polarized, then the emitted photons are circularly polarized

Angular Distribution of Produced Photons

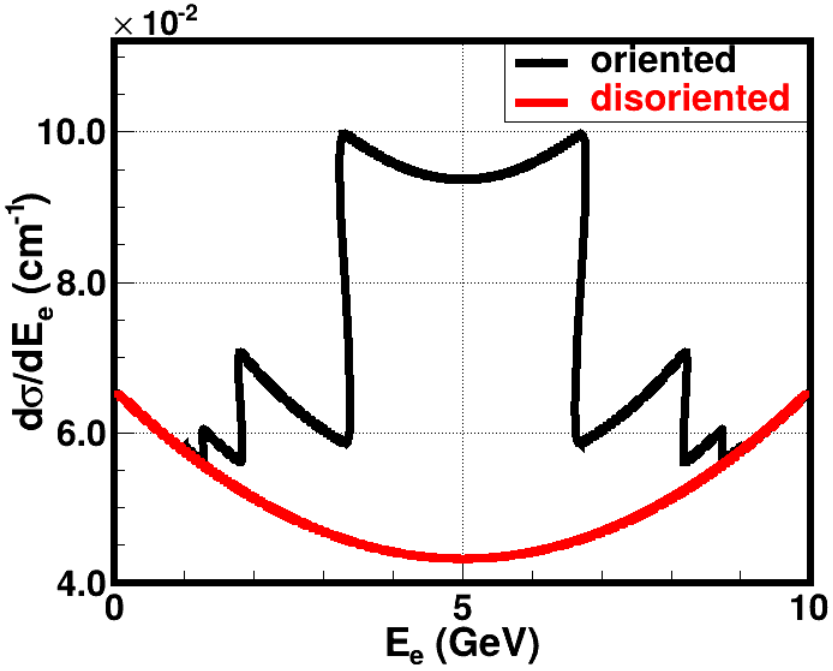


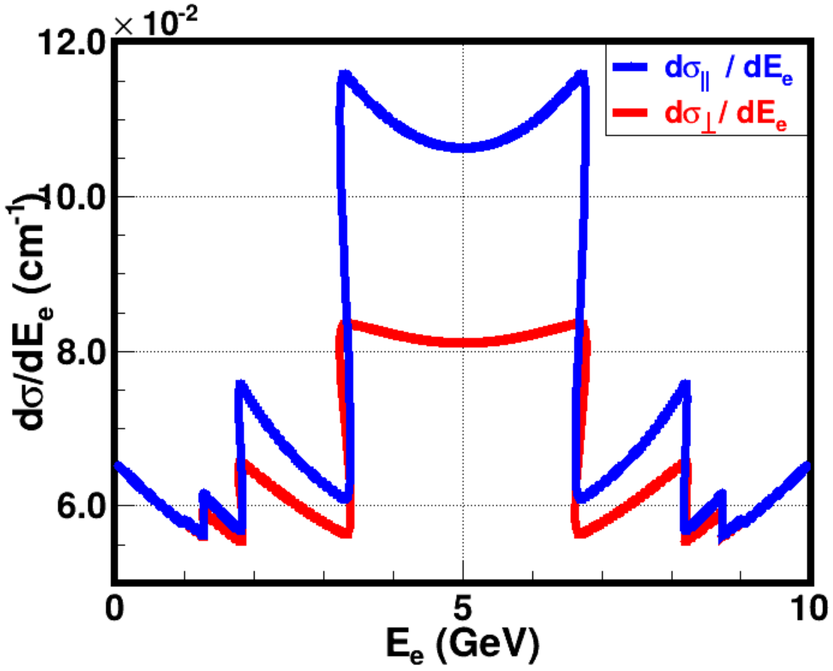


Collimation angle 25 μrad.

The emission angle of incoherent bremsstrahlung photons distributed as ~ $1/\gamma$. But in case of CB, there is a strong correlation between the energy of the coherent peaks and the angle of photon emission with respect to the incident electron direction. By collimating the photon beam, one can eliminate photons beyond a certain angle, and narrow the width of the peaks in energy.

Coherent pair production in single crystals





The difference in $d\sigma_{\parallel}/dE_e$ and $d\sigma_{\perp}/dE_e$ can be used for photon linear polarization measurement.

The method was used in CERN NA59 experiment for the photon linear polarization measurement

(A. Apyan et al, NIM B 255 (2007) 269–275)

Photon energy 10 GeV

Operating orientation:

$\theta_0 = 3$ mrad wrt the <100> Axis and ψ = 0 is the angle wrt to the (110) plane.

Summary

- **Coherent Bremsstrahlung of electrons in single crystals is unique tool for production of high energy photons with high degree of linear polarization.**
- **Tool for production of high energy and high intensity circularly polarized photon beam, if the primary electron beam is longitudinally polarized**
- **Small polar angle distribution which is correlated with the energy of the emitted photon.**
- **Tunable peak energies by crystal orientation.**
- **The CB become more intense at higher energies**
- **Crystal Polarimetry technique is a fast-monitoring tool of the photon beam polarization measurement.**
- **Can be used for high intensity polarized positron production.**

Summary

- **There should be a difference in the radiation (or coherent) of the electrons and positrons due to the opposite charge of the particles. But this is more seen in the low energies. For the high energy region (tens of GeV) this difference is negligible. There is no difference in radiation formulas of CB based on the first Born approximation**
- **Monte-Carlo simulation code is ready for use based on (A. Apyan, *NIM B* 255 (2007) 269-275).**
- **The MC Code was used for the prediction and the analysis of CERN NA59 experiment.**