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Hybrid Positron Source for FCC-ee

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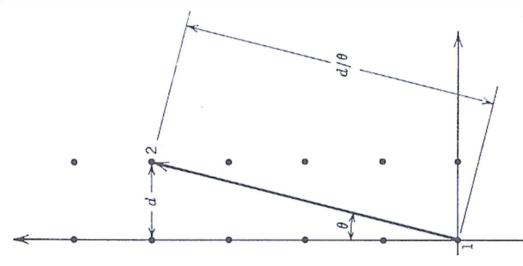
ABSTRACT We study a hybrid positron source based on the radiation of high energy (GeV) photons by coherent bremsstrahlung in the oriented single crystal, and a subsequent amorphous target for the photons. The primary electron beam could be accelerated to 4.46 GeV energy for the current setup of FCC-ee[1]. It is possible to set photon radiation peak on different energies with the proper orientation of the crystal. Second target will be used to convert photons into e+e- pairs. Then positrons with energy around 1.54 GeV will be captured and send to the dumping ring. Monte-Carlo simulations were done to find the proper orientation of the radiator crystal for generating intense high energy photons. These photons passing the target converter will produce high energy e+e- pairs in the vicinity of 1.54 GeV.

Coherent Bremsstrahlung



Coherent Length

$$\ell_{coh} = \frac{1}{q_{min}} = \frac{2E_1E_2}{\omega m}\lambda_c \sim 10^{-7}\text{ cm}$$

$\vec{q} = \vec{g}$ Bragg/Interference condition

The distance corresponding to the inverse value of transferred momentum is a coherent length[2]. When the energy of the particles increases, the effective dimensions of the region in the direction of the particle motion (coherent length) also increase. At rather high energies the coherent length becomes so large that interaction with the medium, generally speaking, cannot be represented as a sum of independent cross sections with individual atoms.

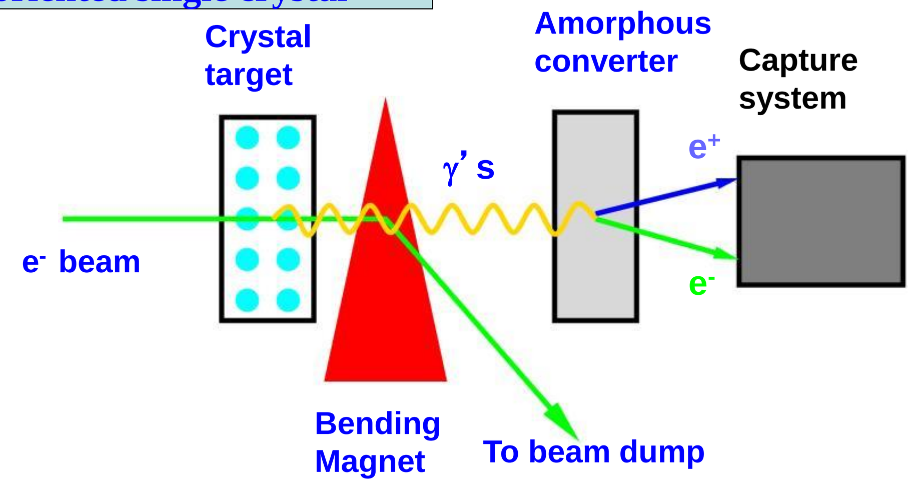
The Method

Separate crystalline target for gamma production

Separate amorphous (or crystal) target for e+ production:

Step-1: Produce gammas by CB in oriented single crystal

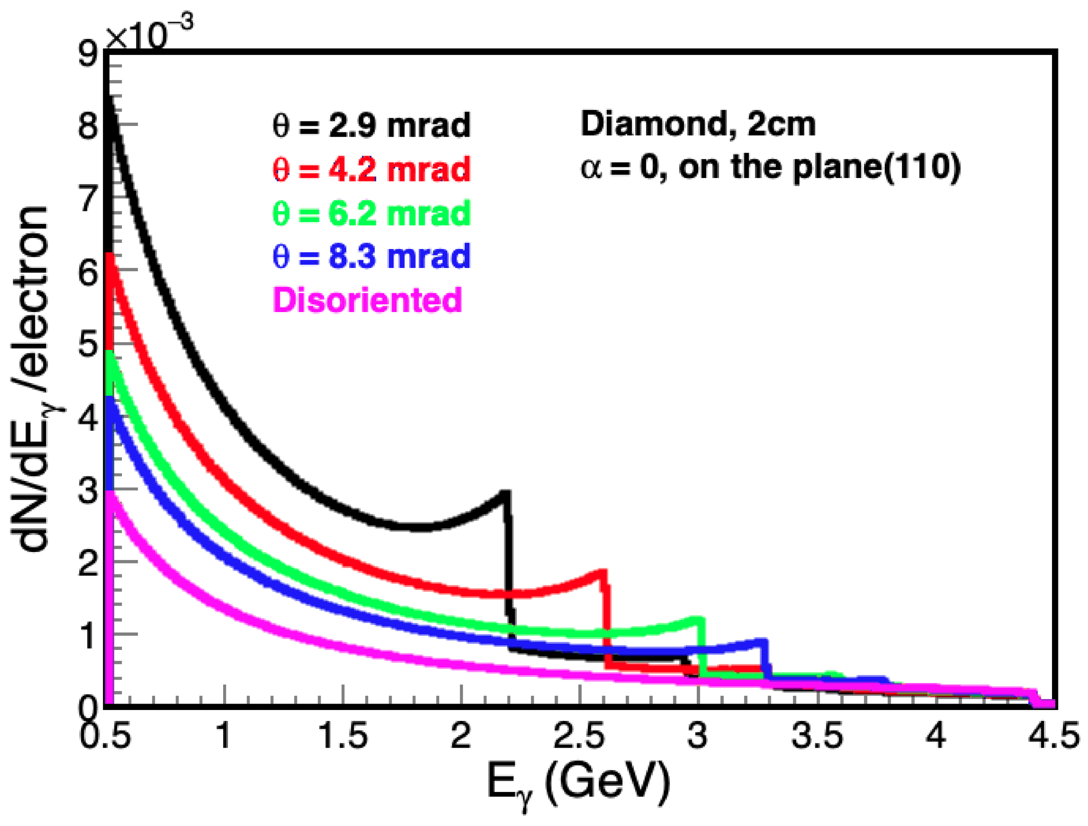
Step 2: Convert γ's to e+



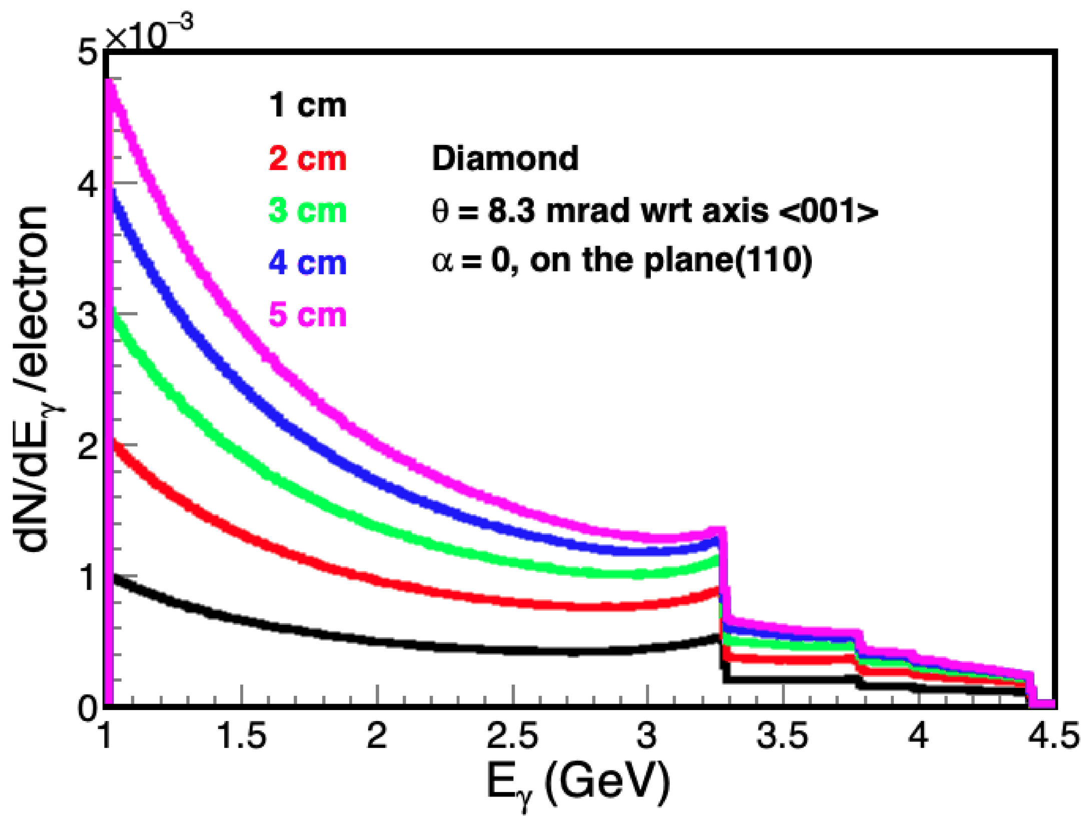
Target#1: uses an aligned single crystal diamond as a radiator for an electron beam to make a photon source instead of using an amorphous target. We will exploit the enhancement of photon radiation via the mechanism of Coherent Bremsstrahlung (CB)[3]. Additionally, if the incoming electron beam is longitudinally polarized, then the produced photons are circularly polarized due to conservation of angular momentum [4].

Target#2: produces positrons by the conversion of photons in a high Z material, such as W, W-Re, Ti etc. If the incoming photon beam is circularly polarized then the produced positron beam is longitudinally polarized due to the conservation of the angular momentum.

Aligned Diamond Crystal as a γ Source Monte-Carlo Simulation Result



Number of photons per electron with different alignment angles of the diamond crystal

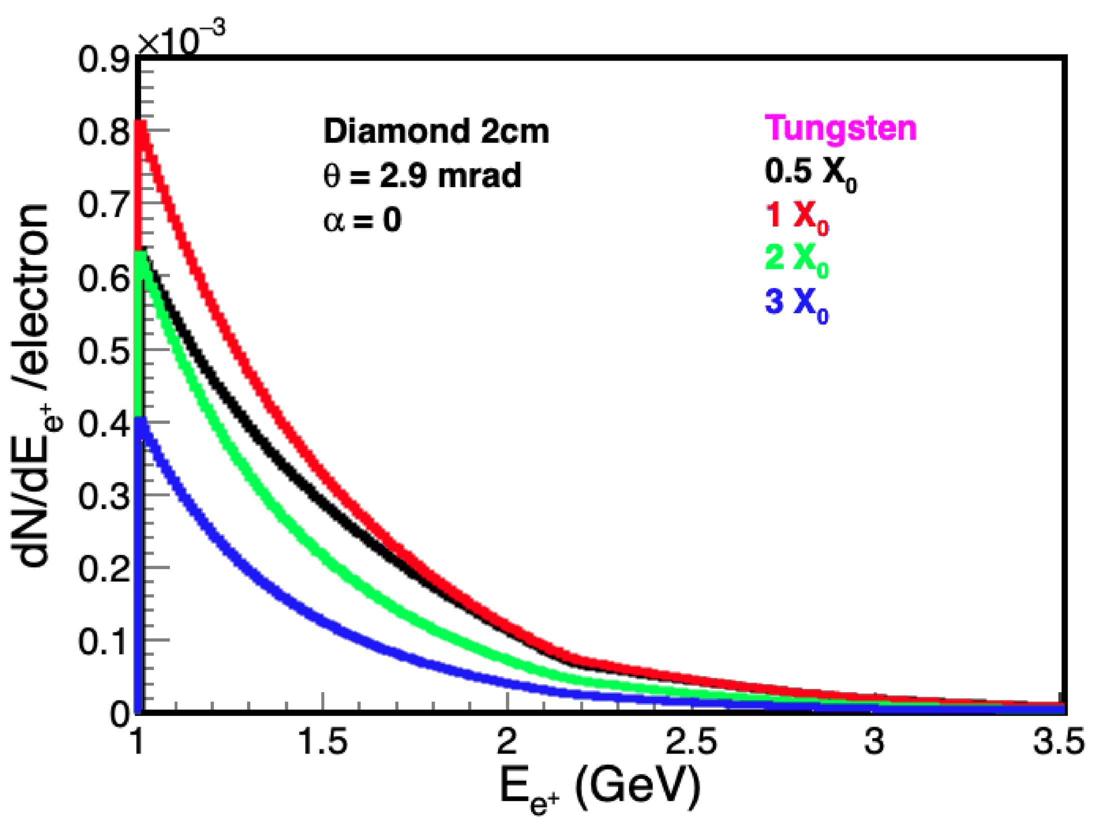


Number of photons per electron with different thicknesses of the diamond crystal

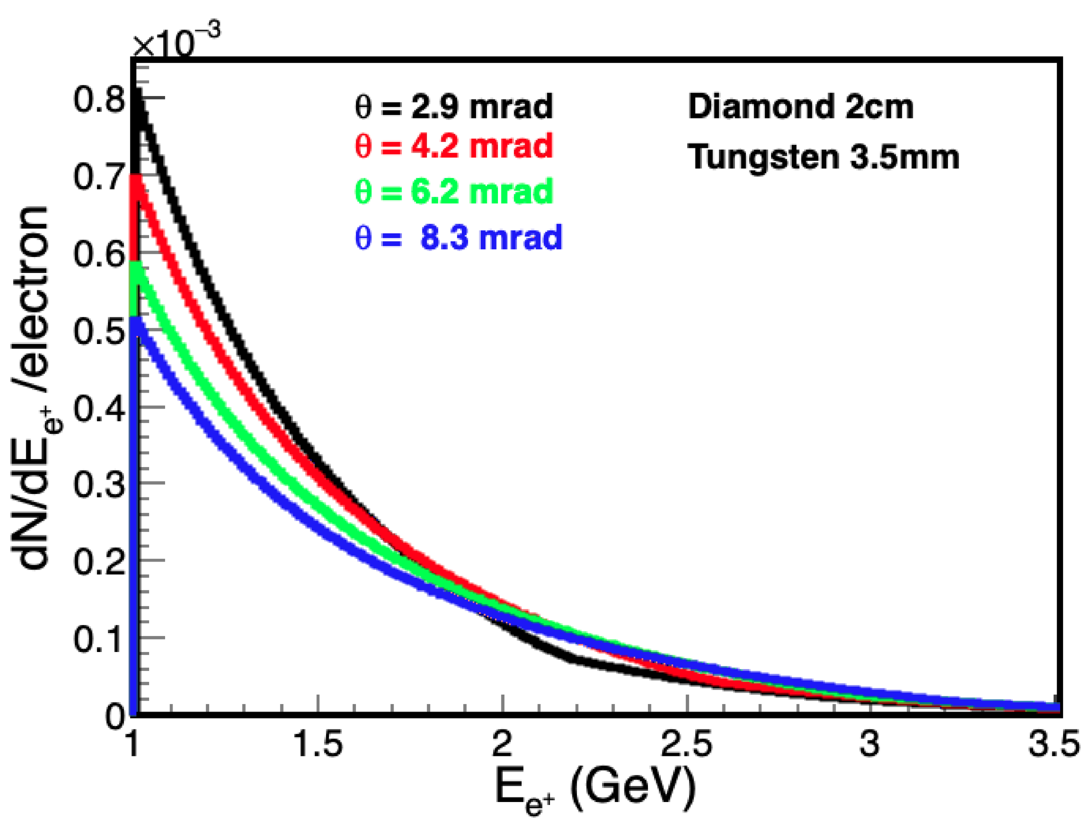
The main peculiarities of the proposed method

1. This method is simple since it does not require further acceleration of low energy positrons up to the dumping ring energy, 1.54 GeV.
2. The coherent photon peak is chosen in such way that the produced number of positrons is maximum in the energy range 1.42 – 1.66 GeV.
3. High energy positron production leads to the small emittance of the produced positron beam. The radiation and pair production angles is in order of ~1/γ. For example positron production angle is ~25mrad for 20MeV initial photons and ~0.3mrad for 1.54 GeV photons.
4. Another advantage is the possibility of producing longitudinally polarized positrons starting with longitudinally polarized electrons.

Positron Yield from amorphous Tungsten converter Monte-Carlo Simulation Result



Produced positron spectra depending on the thickness of Tungsten converter.



Produced positron spectra depending on alignment of the diamond crystal

Positron yield depending on the diamond crystal orientation and tungsten converter thickness per incoming electron

	0.5 L_R (10^{-3})	1 L_R (10^{-3})	2 L_R (10^{-3})	3 L_R (10^{-3})
2.9mrad	6.5	7.4	4.8	2.7
4.2 mrad	5.9	7.0	4.8	2.8
6.2mrad	5.1	6.2	4.4	2.7
8.3mrad	4.5	5.6	4.1	2.5

Energy range 1.54±7.8%. 1.42 -- 1.66 GeV

REFERENCES

1.. FCC CDR, Volume 2, 2019.
2.M.L. Ter-Mikaelyan. High Energy Electromagnetic Processes in Condensed Media. John Wiley and sos Inc., New York, 1972.
3. A.Apyan et al., NIMB, 171 (2000) 577.
4. H. Olsen et al., Phys. Rev., 114 (1959) 887.

Summary A promising approach to use crystalline targets providing enhancing photon production in certain spectral regions via mechanism of coherent bremsstrahlung is given. One of the advantages of the method is the direct high-energy positron beam production. The dependence of the efficiency of positron production on the target material, thickness, orientation as well as parameters of the positron beam at various energies are presented. More detailed studies are required to find the optimal orientation of the crystal radiator to maximize the number of photons. The intensity of Coherent bremsstrahlung increases with the increase of initial electron beam energy. We plan to carry out Monte-Carlo simulations for the initial electron beam with 10GeV energy. This will increase the number of photons and subsequently the number of produced positrons. Monte-Carlo study of producing polarized positrons will be done as well.