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POSITRON PRODUCTION AND ENERGY DEPOSITION STUDIES WITH FLUKA

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Abstract. - The CLIC positron production is based on well-known conventional method, utilizing amorphous target and a solenoid magnet to focus produced positron through pre-injector Linac. In this work, we have focused on the CLIC positron production studies with extensively used FLUKA simulation code. Distribution of the energy deposition in the target has also been examined with the FLUKA for different parameters like beam spot size and target thickness. The FLUKA simulation calculations are in good agreement with previous work done by using EGS4 code.

Keywords

CLIC Positron Production, Energy Deposition, FLUKA.

INTRODUCTION

The Compact Linear Collider (CLIC) is a study for a future electron-positron collider at CERN. It will have a centre-of-mass energy up to 3 TeV, but relies on new dual-beam accelerating technology which is still under consideration. The CLIC positron source is based on the conventional scheme. In this scheme, the medium energy (several GeV) and high intensity electron beam hits a high Z material target to generate electron positron pairs. While emerging electrons from the target are accelerated to the dumping region, positrons are accelerated to the pre-injector Linac [1]. Three main schemes to produce positrons are being considered by the linear collider community. The first is to use electron beam and amorphous target (conventional method), the second is to use electron beam, crystal target and amorphous target (channeling process) and the third is to use polarized gamma rays and amorphous target (Fig. 1). Each of these three concepts has their own problems connected with their technical complexity.

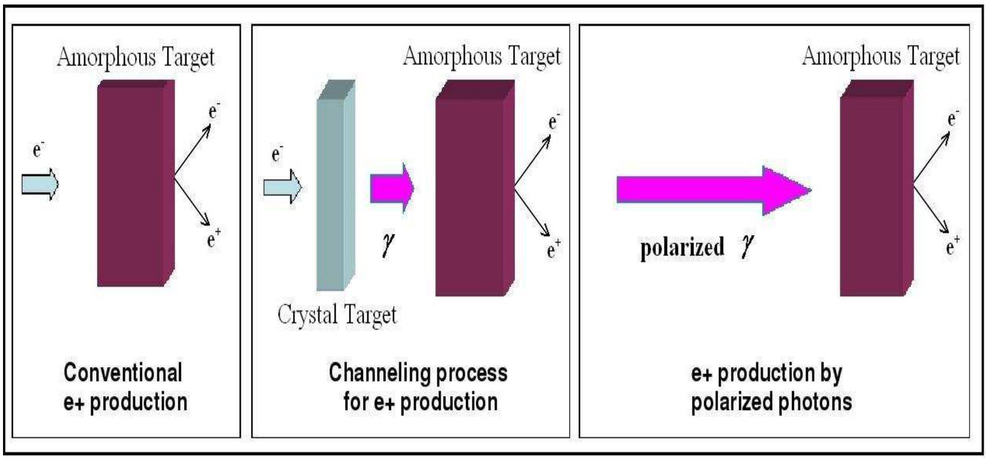

Figure 1: Sketch of Three Main Positron Production Methods

In order to achieve requested luminosity, the sources should be designed to inject positrons at rates at least twice those expected at their interaction points which is approximately $1.0x10^{14}$ positrons per second [2,3]. To produce such high intensity positrons with the conventional scheme, the primary electron beam should have 333 nC/pulse and energy of 2 GeV [4]. The conversion target is heated by the irradiation of such high intensity electrons. Thus the energy deposition studies in the target are important to overcome heating and distortion problems for the stable long-term operation. The Tungsten-Rhenium (W_{75}-Re_{25}) alloy target was selected to be used for CLIC positron production source. The Peak Energy Deposition Density (PEDD) allowed in a tungsten target is 35 J/g [5].

In this work, FLUKA simulation code was used for both positron production and energy deposition calculations. FLUKA is a general purpose tool for calculations of particle transport and interactions with matter. It has large application areas such as accelerator shielding, target design, detector design, neutrino physics and radio-therapy [6]. It has also been used to compute the total energy deposition and particle energy spectra [7-9].

POSITRON PRODUCTION

The CLIC positron production is based on conventional scheme, using an electron beam of 2 GeV, a converter target and a solenoid magnet. In the FLUKA simulation, electron positron pairs have been produced from the W_{75}-Re_{25} alloy target of 4.5 X_0 thickness. The incident electron beam energy, target material and its thickness were foreseen for CLIC positron production. Figure 2 shows, the variation of the produced electron-positron fluencies as a function of their energies. As can be seen from the distributions, electron and positron fluencies increase at first then decrease with increasing their energies, peaking at around 10 MeV, which has an appropriate value for energy acceptance for Adiabatic Matching Device (AMD) [4]. The value of the positron yield is also dependent on several parameters such as incident beam energy and radius and target thickness. The peak fluence value of produced positron is given as 11 MeV in Ref [4] for 2 GeV incident electrons on W_{75}-Re_{25} alloy target of 4.5 X_0 thickness.

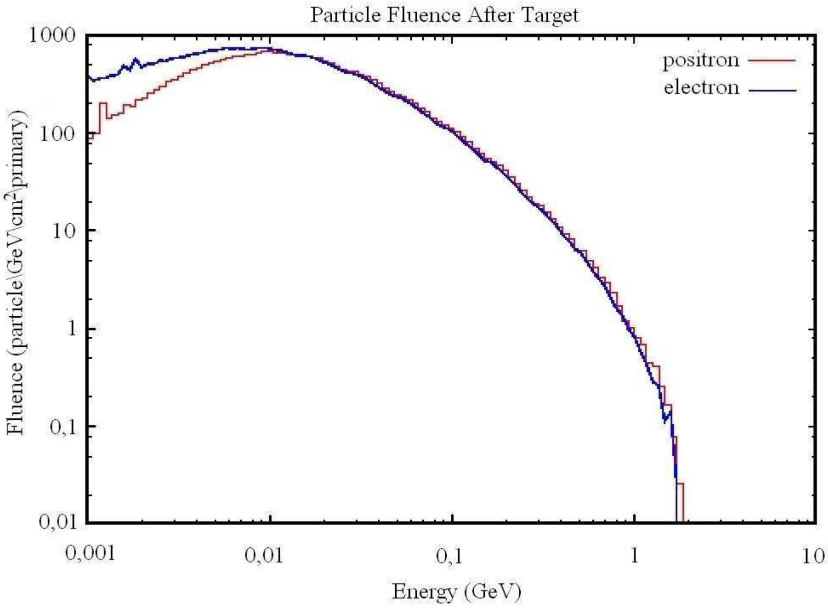

Figure 2: Electron-positron fluencies as a function of their energies.

ENERGY DEPOSITION

The beam power deposition is very dependent on the target thickness and incident electron beam radius. In order to calculate the deposited beam power upon the target thickness, the $W_{75}Re_{25}$ target at different thickness was irradiated by electron beam of 1.6mm radius with an energy of 2 GeV. The FLUKA calculation of beam power deposition for different thickness of the target is shown in Figure 3. The result is in good agreement with the EGS4 simulation result obtained in previous works [4]. As shown in the Figure 3, the beam power deposition is quite dependent upon the target thickness. This dependence is rather large around the design thickness of 4.5 X_0. According to the simulation, by decreasing the thickness from the 4.5 X_0 to 4 X_0, the beam power deposition is reduced by around 20%.

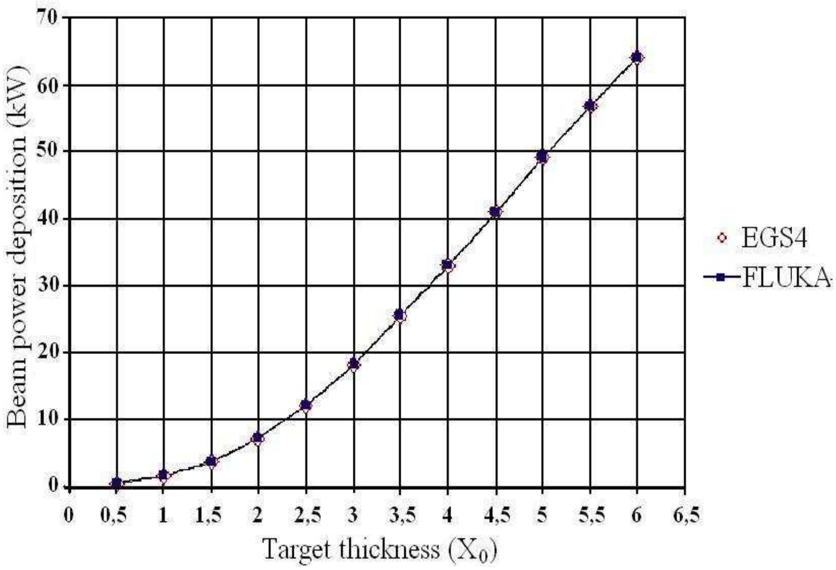

Figure 3: Beam power deposition versus target thicknesses for electron beam of 1.6 mm radius.

Beam power deposition on the $W_{75}Re_{25}$ target of 4.5 X_0 thickness was calculated by the irradiation of the 2 GeV electron beam with the different radius from 1 mm to 2.4 mm. The FLUKA calculation of the variation of beam power deposition with the beam radius is shown in Figure 4. According to this result, the incident beam spot size can be enlarged to keep the beam power deposition well below the limit.

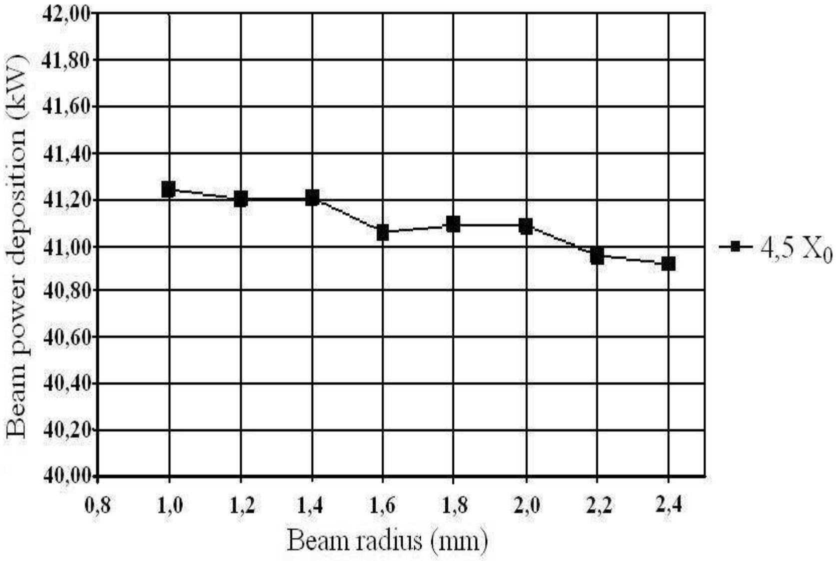

Figure 4: Beam power deposition versus beam radius for target of 4.5 X_0 thickness.

In order to estimate the peak volume density, the energy deposition in each meshed volume (dx = 0.5mm, dy = 0.5mm, dz = 1.7mm = 0.5 X_0) was calculated. The maximum deposited energy in the target volume has been calculated as 1.35 MeV per incident electron. This value was calculated as 1.3 MeV with the EGS4 simulation in previous works [4]. This small difference is due to the behaviour of the monte carlo calculations. Here the cell volume is dV = dx dy dz = 0.425 mm^3.

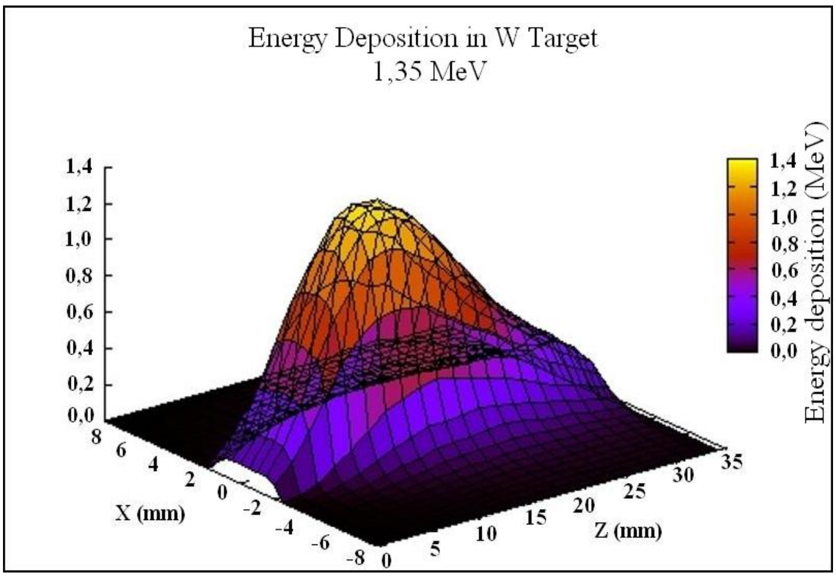

Figure 5: Energy deposition distribution in amorphous target

In order to see the whole shape of the shower distribution around the peak energy deposition density, the simulation was performed for the depth of 10 X_0. For

208x10^{10} electrons per pulse, the peak density per volume was calculated as 0.66x10^{10} GeV/mm^3 in. This value was 0.64x10^{10} GeV/mm^3 in EGS4. The peak density resides around the depth of 4.0 X_0 for the CLIC design [4]. Fig. 6 shows the energy deposition density distributions calculated with EGS4 and FLUKA codes.

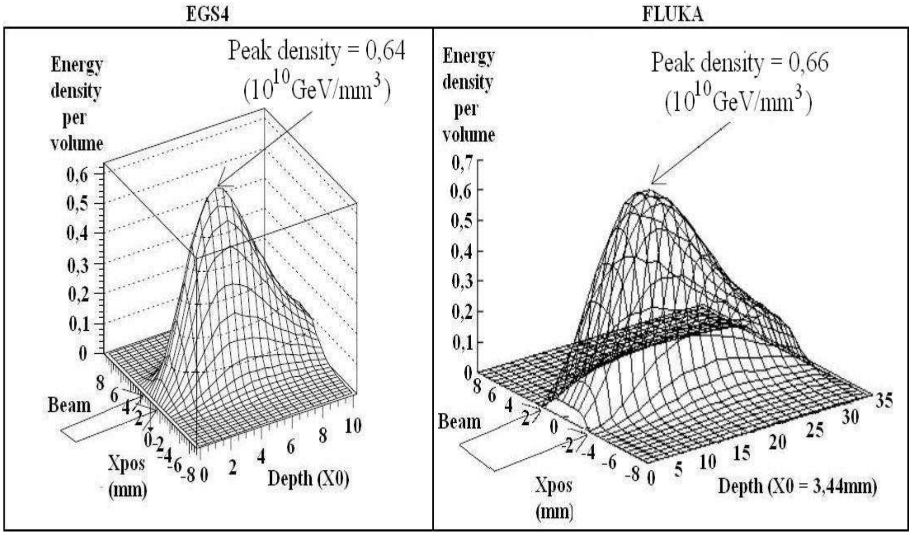

Figure 6: Energy deposition distributions in the target

CONCLUSION

In this work, produced electron-positron fluencies and the distribution of the energy deposition in the CLIC conventional target was studied with the electromagnetic shower simulation code, FLUKA. The results were well agreement with previous work done by EGS4 code. These results showed that, FLUKA code can be used for the other positron production process.

ACKNOWLEDGEMENTS

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