OVERALL SIMULATION OF A POSITRON BEAM GENERATED BY PHOTONS FROM CHANNELED MULTIGEV ELECTRONS

X.Artru
Institut de Physique Nucléaire de Lyon - IN2P3
69622, Villeurbanne Cedex, France

R.Chehab
Laboratoire de l'Accélérateur Linéaire - IN2P3
91405 Orsay, France

A.Jejcic, J.Maillard, J.Silva
Collège de France-IN2P3
75231 Paris Cedex 05, France.

Abstract

Simulations of a non-conventional positron source, using 1.5 - 20 GeV electron beam impinging on an assemblage of a tungsten crystal oriented along its <111> axis and an amorphous target of the same material,are presented.An overall simulation taking into account photon creation in the optimum length of the crystal, positron generation in the target and also positron capture and transport, allows optimization of the source. Positron yield has been calculated for different operating conditions. Comparisons with classical sources are presented. [1]

1. Introduction

Increasing interest in high intensity, low emittance positron sources for linear colliders pushed on different approaches.First of all extrapolation of conventional positron sources to the required parameters of linear colliders are worked out. They led to positron generation by high energy electron beams impinging on thick targets. Valuable positron yields are met by operating adequate setups (high gradient RF sections, damping rings) in order to minimize transverse and longitudinal phase extensions of the beam [1],[2]. Developments of rotating targets are undertaken to circomvent the thermic effects which represent the fundamental limitation [3].

Another direction of development is represented by the tentative to generate electron-positron pairs in thin converters which thickness is only a fraction of radiation length. In order to achieve fluxes comparable to those obtained with thick converters, photons are required with very high rate much higher than those provided by Bremsstrahlung. Nowadays two ways are being explored.

[1] We gratefully acknowledge Prof.V.N.Baier for fruitfull discussions. We are indebted to B.Mouton for software assistance.

The first, proposed for the VLEPP collider [4], is based on utilization of a very high energy electron beam ($E^- \geq 100GeV$). The electrons generate circularly polarized photons in a very long (150 m) helical undulator ; yields above unity are expected.

The second way, presented recently [5], takes advantage on the channeling effect observed for electrons in oriented crystals. Operated electron energies are expected to be much lower and the photon radiator is on millimeter scale. Silicium and Germanium crystals have been already considered [5]. Hereafter an alternative solution using tungsten crystal axialy oriented on its <111> axis and associated to an amorphous thin tungsten converter is presented.

2. Sources using channeling

In a previous report [5] simulations have been worked out for a positron source made of Ge or Si crystals 1 cm long oriented on their <110> axis followed by tungsten amorphous targets of 0.5 and $1X_o$ thickness. For 20 GeV incident electrons, yields above unity were computed.

On the basis of the theoretical analysis developped by V.Baier et al. [6] and also stimulated by the simulation results already available on Ge and Si crystals a proof of principle experiment on a tungsten crystal was proposed [7]. An extensive simulation analysis was therefore undertaken aiming at a positron source based on electron channeling with high photon rate, high total positron yield and weak transverse momentum.

2.1 Simulation conditions

The fundamental physical process, radiation of channeled electrons in a crystal, is simulated by an ad hoc code [8] which calculates the electron trajectories, the photon emission probabilities and their complete kinematics. This code is based on the semi-classical Baier-Katkov formula for radiation in non-uniform

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field [9] and takes into account multiple scattering.

Simulation was done in software environment usual to High Energy Physics. The detector simulation code GEANT was adopted as the basis for working out the needed calculations. In this framework the code simulating channeling was introduced as an event generator. As an implementation on a parallel computer was foreseen from the very beginning the GEANT choice was also welcome [10].

For the initial step reported here the simulated setup was rather simple; more elaborated examples will be simulated next. The setup is made of a tungsten crystal oriented following the <111> axis, a cylindrical piece of amorphous tungsten and a drift space with a longitudinal magnetic field. So as to get small transverse momenta, tungsten amorphous targets present a thickness less than $1X_o$. Initial electrons kinematics were generated randomly according to normal distribution originated by a specific input. A set of typical values could be recalled :the transverse momentum was 5 $10^{-4)}$ of the longitudinal momentum at E^-=2 GeV,the impinging electron beam (usually ,one thousand particles) had 0.1 cm radius and crystal was considered at room temperature. The same electron set was used for simulating the amorphous converter and the assemblage crystal-amorphous.

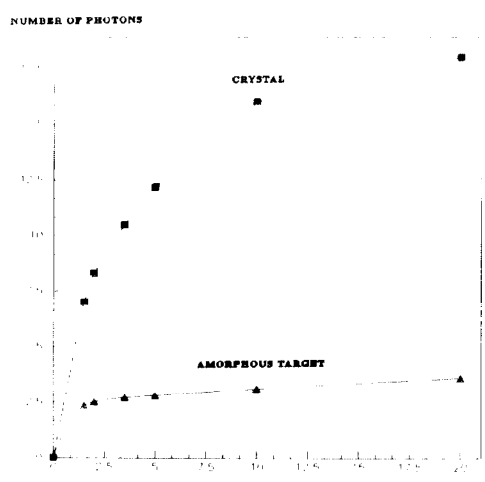

Fig.1 Photon yield vs incident electron energy

Results concerning the amorphous part of the converter were compared with EGS [11] output, the shower simulation code we have used extensively for the design of amorphous converters. Good agreement was obtained.

2.2 Results on Photons

Photon yield dependence on electron incident energy is shown on the figure 1. Comparison between crystal and amorphous radiator - 1 mm thick both - exhibits an enhancement factor of 3 to 5 in the energy range 1.5 to 20 GeV.

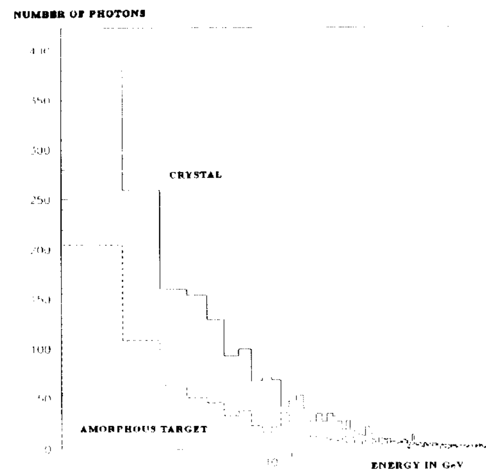

Fig.2 Photon spectra for E^-=2 GeV.

Photon spectrum including Kumakhov and bremsstrahlung photons, at crystal exit, has an average value of 95 MeV ; whereas average energy of bremsstrahlung photons from an amorphous target of the same thickness is 172 MeV. On the figure 2 the two spectra are superimposed.

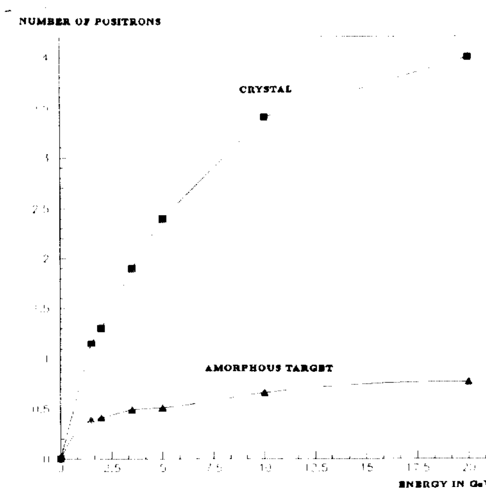

Fig.3 Positron yield

2.3 Results on Positrons

Hereater are presented the essential features of positron production. The chosen standard case concerns the configuration involving 1mm tungsten crystal followed by 0.25 X_o amorphous tungsten. Comparisons with amorphous targets of same overall thickness (0.54 X_o) are made.

Positron yield : the positron yield dependance on incident electron energy was examined up to 20 GeV. The results reported on figure 3 exhibit an enhancement factor between 3 and 5.

Positron energy spectrum : for 2 GeV incident electron energy positrons have an average energy of 76 MeV (figure 4). Between 1.5 and 20 GeV the average positron energy scales from 70 to 190 MeV.

Positron transverse momentum : For E^{-}=2 GeV, its average value is 6.8 MeV/c . As one could expect its average value increases only slightly in the incident energy interval (1.5 - 20 GeV) for a given thickness; multiple scattering gives the dominant contribution to the transverse momentum.

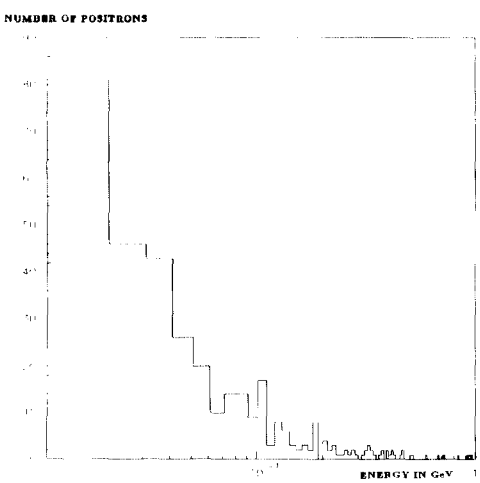

Fig.4 Positron energy spectrum($E^{-} = 2$GeV)

2.4 Matching optics

The source (crystal + amorphous) has been completed with a large energy acceptance matching optics. The chosen device was the SLC system with an adiabatically tapered magnetic field [2]. This field is defined by : $B = B_0/1 + \alpha z$ with B_0 = 5 Tesla, α = 20 m^{-1}.

3. Some comparisons

A source made of 2mm tungsten crystal and 2.6mm tungsten amorphous target gives an accepted yield of 1e+/e-,in SLC system, when initiated by a 20 GeV electron beam. This result may be compared with that obtained with a composite source made of 10mm Ge or Si crystal followed by 3.5mm amorphous tungsten target, which has been previously reported [5].

Energy deposition in such a source represents a little more than one percent of the incident energy.This is considerably lower (about 30 times) than a conventionnal source generated by 1mm radius electron beam of 20 GeV on a $6X_o$ target.

4. Summary and Conclusions

A crystalline positron source, simulated as an assemblage of a tungsten crystal oriented on its <111> axis associated to an amorphous target of the same material, presents interesting features :

- A higher level of photon radiation compared to classical Bremsstrahlung.
- A positron production enhancement of the same order as the radiation in- crease.
- The possibility of using thin amorphous targets behind the crystal, which allows weak positron transverse momentum and lowers the amount of deposited energy in the target.

These arguments led to a proposal for a test at the Orsay linac.

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