On the Possibility of Producing Low Energy Positrons with SR from a Superconducting Wiggler

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A positron can be a good probe of materials. It can be used as a probe of Fermi surface, defects, surface and interface. Much study has been performed by using low-energy positron beams in the field of atomic physics, solid state physics, materials science, etc. [1]

Using γ-rays with energy well above 1 MeV, one can produce positrons in matter through the electron-positron pair production process. These positrons can be collected and used as a positron beam. Since the positron beam with very low energy is required in many fields of its application, positrons must be decelerated to a few eV with a suitable moderator. The efficiency of moderation is typically 10^{-3}–10^{-4}, and thus the flux of an incident γ-ray must be high enough.

In synchrotron radiation (SR) facilities, like SPring-8, such an intense γ-ray will become available if one installs a high field superconducting (S/C) wiggler in the storage ring. Necessary field strength of the S/C wiggler will be 8 to 12 Tesla if one aims at a positron beam intensity of 10^{10} [slow-e^+/sec]. This method of using SR has an advantageous point that, when compared with other methods, radiation hazard is drastically reduced and induced radio-activity of target and moderator can be eliminated [2].

The yield of positrons can be estimated in the following way. For a photon incident on a target slab with energy ε, one can evaluate the number of produced positrons $\kappa(\varepsilon)$ by using the simulation code EGS4 [3]. Since the photon flux $F(\varepsilon)$ is readily obtained, the total number of produced positrons are calculated by integrating $F(\varepsilon)\kappa(\varepsilon)$ over the photon energy ε. The results are summarized in Table 1 for 100 mA of the beam current. In this table κ_{slow} is a conversion rate from positrons created in the target slab to low energy positrons. The value of κ_{slow} is typically 10^{-3}-10^{-4}, but it depends strongly on the slab thickness and the arrangement of target and moderator.

A crude estimation of the energy distribution of positrons can be made by assuming that one half of an incident photon energy converts to the energy of a positron and another half to that of an electron: $\varepsilon/2 = mc^2 + T$, where m is the electron mass and T is the kinetic energy of an electron (or a positron). Then the energy distribution is obtained by plotting the integrand $F(\varepsilon)\kappa(\varepsilon)$ as a function of T. We show the result in Fig. 1. Though crude, our estimation would be enough for qualitative description of the energy distribution. For example, one sees that most positrons are produced with energy below 1MeV.

From these we can expect that 10^8-10^{10} low-energy positrons will be produced per second, millirad of the orbit arc and 100 mA of the beam current.

We have also checked the effects of a S/C wiggler on the electron beam. The results are summarized in ref. [4].

Table 1: The number of low-energy positrons produced in a tungsten slab per second, millirad of the orbit arc and 100 mA of the beam current. The results for 5 Tesla field are also shown for comparison.

Slab Thickness [mm] \ Wiggler Field [T]	5	8	10
0.05	$6\times10^{9}\times\kappa_{slow}$	$8\times10^{10}\times\kappa_{slow}$	$2\times10^{11}\times\kappa_{slow}$
0.5	$6\times10^{10}\times\kappa_{slow}$	$8\times10^{11}\times\kappa_{slow}$	$2\times10^{12}\times\kappa_{slow}$
5	$5\times10^{11}\times\kappa_{slow}$	$7\times10^{12}\times\kappa_{slow}$	$2\times10^{13}\times\kappa_{slow}$
50	$1\times10^{12}\times\kappa_{slow}$	$2\times10^{13}\times\kappa_{slow}$	$5\times10^{13}\times\kappa_{slow}$
100	$1\times10^{12}\times\kappa_{slow}$	$2\times10^{13}\times\kappa_{slow}$	$5\times10^{13}\times\kappa_{slow}$

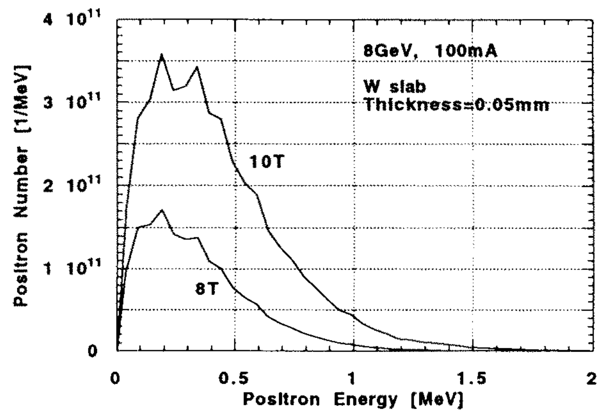

Figure 1: Energy distribution of positrons produced in a tungsten slab.

References

[1] P.J. Schultz and K.G. Lynn, Rev. Mod. Phys., **60**, 701 (1988).

[2] G. Kulipanov, N.A. Mezentsev and A.N. Skrinsky, Rev. Sci. Instrum., **63**, 289 (1992); G. Kulipanov, in Proc. of Workshop on Fourth Generation Light Sources, SSRL 92/02, p.440.

[3] W.R. Nelson, H. Hirayama and D.W.O. Rogers, "The EGS4 Code System", SLAC-265 (1985).
[4] K. Soutome, A. Ando, S. Daté, Y. Miyahara, T. Nakamura and H. Tanaka, in Proc. of Fourth European Particle Accelerator Conf. (1994), p. 660.