Monte-Carlo simulations for timing-system of EPOS at ELBE in Research Centre Dresden-Rossendorf

M Butterling¹, M Jungmann¹, V Bondarenko¹, S Sachert¹, G Brauer², W Anwand² and R Krause-Rehberg¹

¹ Department of Physics, Martin-Luther University, 06099 Halle, Germany
² Research Center Dresden-Rossendorf, PO Box 510119, 01314 Dresden, Germany

E-mail: maikbutterling@web.de

Abstract. Most of the monoenergetic slow-positron beam systems capable for positron lifetime spectroscopy are bunched from a continuous beam (e.g., the PLEPS system in Munich). The EPOS system at the ELBE radiation source will use the original time structure of the 40-MeV electron beam which is utilized for pair production. This is an infinite repetition of very short electron pulses (< 5 ps) with an adjustable repetition rate (typical 77 ns). In both cases, the time structure of the positron beam needs sharpening so that the time focus is located at the sample position. This is realized by the bunching system. Usually, double-slit bunchers are used. They are operated by a sinusoidal RF-voltage. This bunching requires an adjustment according to the final positron energy (0.5...30 keV), since the acceleration of the positrons shifts their time focus. Monte-Carlo simulations were done to investigate the effect of different methods of time focusing. One method is the variation of amplitude of the buncher RF-voltage. Another improvement is the combination of such a buncher voltage variation with a variable drift path acceleration short before the final acceleration which is operated by a DC voltage. Our simulations show that indeed a combination of a buncher variation with a drift path gives the sharpest positron pulses when both devices are supplied with individual voltages for each positron implantation energy.

1. Introduction
At Research Center Dresden-Rossendorf the 40 MeV electron beam ELBE (Electron Linac for beams with high Brilliance and low Emittance) is used to generate positrons by pair production. An advantage of this source is the time structure (bunch width about 5 ps; repetition time 77 ns) which makes ELBE to an ideal host for a bunched positron beam. The following illustration shows the EPOS system (ELBE Positron Source) in a simplified way: only those elements are included which are important for the timing system. More detailed information is given in [1].

Figure 1. Simplified scheme of the EPOS beam with focus on the timing system.
The ELBE primary beam is partly converted by pair production into fast positrons. These positrons are cooled down in a moderator foil (tungsten or platinum) and are extracted to the positron lab as a monoenergetic positron beam with an energy of 2 keV. The extremely sharp time structure of the primary electron beam allows the realization of the positron lifetime spectroscopy in a unique way. For this purpose, the positron beam is treated by a system of choppers, double-slit bunchers and an additional drift path short before the final acceleration to improve the positron beam structure thus making the system very simple and effective. Without these devices the time structure of the positron beam will be broadened and positron lifetime measurements would be impossible.

2. Monte-Carlo simulation of the lifetime
Monte-Carlo simulations were done to calculate the dependency of the time structure of the positron beam for different settings (i.e. change of beam energy, variation of the buncher RF amplitude and a variable drift path). The converter has a fixed energy of 2 keV with an expected standard derivation of < 10 eV. To realize energies between 0.2 keV and 30 keV the positrons will additionally be accelerated close to the sample. The simulations calculate the timing behavior of the positron bunches. The result is the full width at half maximum (FWHM) of the positron bunch and the location of the time focus of the bunch. These parameters are used to evaluate the benefit of the two devices. Each simulation was done for a number of 2000 positrons. The following picture illustrates the correlation between positron energy, position of the time focus and the FWHM of the positron bunch at sample position for a fixed buncher RF-voltage (the simplest case):

![Figure 2](image)

Figure 2. Time focus position and FWHM at a sample position of 11 m (distance from the electron-positron converter) for different positron acceleration energies.

The result is a useless FWHM of about 1750 ps (a good value would be lower than 100 ps) due to the shift of the time focus. Figure 2 illustrates the importance of a timing-system that improves the time structure of the beam. A first method is to vary the buncher RF-voltage for each implantation energy.

3. Variation of the buncher RF-voltage
For this part of simulation the buncher RF amplitude was varied for every energy with the aim of moving the time focus to the sample position. The plot of these data (figure 3) shows that for lower energies (up to about 5 keV) a shift of the buncher RF amplitude has a great influence on the FWHM at sample position. Otherwise in this region the buncher RF-voltage has to be changed more than for higher energies (from 10 keV to 22 keV). The best value for the FWHM given by this method is nearly 60 ps.
To visualize the importance of a stable buncher RF-voltage the relation between a small shift in the buncher RF-voltage and the FWHM of the positron pulse was simulated. The result (figure 4) shows that for lower positron energies (up to 2 keV) a small shift of the buncher RF-voltage has no great influence on the FWHM. A stability of the voltage of 1 or 2 V seems to be enough.

4. Combination of a buncher with a variable drift path
The other timing method is the combination of the double-slit buncher with a variable drift path (see figure 2) which is operated by a DC voltage. Therefore, the buncher RF-voltage is set to the value that is necessary for the implantation energy of 30 keV (the maximum of the positron energy). Figure 5 presents the relation between FWHM at sample position (and optimum drift path voltage) as a function of the positron energy.

The result is a substantially better FWHM of the positron pulse for lower positron energies (from 3 to 10 keV) compared to the usage of the buncher with varying RF voltage alone. The FWHM in this range is much lower than 90 ps. The minimum FWHM is 30 ps (compare with figure 3, the minimum there was 60 ps).
5. Combination of a buncher with a drift path with individual voltages for each positron implantation energy

To simulate the results of a variation of both voltages (buncher RF amplitude and drift path’s DC voltage) it is necessary to fix the positron energy for each simulation. For each drift path voltage the buncher RF amplitude was varied with the aim to get the time focus at the sample position. Figure 6 presents the influence on the FWHM and gives a comparison between all three methods (see the dashed lines). One can see that in a certain area the FWHM is better as compared with the other methods. The FWHM has a parabolic dependence on the drift path voltage with a clear minimum.

A look at the relation between drift path voltage and buncher RF-voltage indicates a similar behavior for different positron implantation energies.
Figure 7. Relation between optimum buncher RF amplitude and drift path voltage for certain positron energies.

These simulations (like for figure 6) were done for different positron implantation energies to find the minimum FWHM (the minimum of the parabola in figure 6). Figure 8 compares all three methods (variation of the buncher RF-voltage, combination of a fixed buncher with a variable drift path, combination of a variable buncher with a drift path with individual voltages for each positron energy). It is obvious that the combination gives the sharpest positron pulses for all positron implantation energies. One can improve the FWHM of the positron pulses by more than a factor of 2 for some energies.

Figure 8. Comparison between all three methods of bunching.

References
[1] Krause-Rehberg R, Sachert S, Brauer G, Rogov A and Noack K 2006 EPOS - An intense positron beam project at the ELBE radiation source in Rossendorf Applied Surface Science 252 3106–3110