EUROTEV-Report-2005-019-1

Proposal for the auxiliary positron source for ILC

Klaus Floettmann

DESY

October 2005

In order to improve the availability of the ILC an auxiliary or keep-alive source is discussed for the undulator based positron source. The purpose of this source is to allow commissioning and tuning of the positron linac when the electron linac is not operating. In [1] it is proposed to install a ~500 MeV electron injector in the main positron source area and to direct the electron beam onto the target of the undulator based positron source for positron production. The electron injector should deliver a full spec electron beam and can be used directly for commissioning purposes with electrons. The same injector could be used for e^-e^- or $\gamma\gamma$ operation. For this purpose the injector should deliver polarized electrons. If the electron beam is directed onto the target positrons are produced at modest intensity.

This concept has many advantages:

- Since the undulator target and capture optics would be used, the produced positrons could be used for the commissioning of these sections and would have an emittance and orbit practically identical to the positron beam produced with the undulator.
- A standby operation of the auxiliary source can easily be realized, which allows a fast switch over. Since the orbit and emittance of the positrons is nearly identical to the beam parameters of the main positron source the tuning requirement for the injection into the damping ring is minimized.
- Space requirement, investment and operational costs are small.

The specification of the keep-alive source requests a bunch intensity high enough to allow orbit measurements with ILC BPMs, while the request on the pulse train structure (number of bunches per train and bunch distance) is rather loose. Orbit measurements with about 1% of the design bunch intensity seem to be possible with some effort in the BPM electronics and are also requested for other purposes (machine protection, start-up procedures). However, a positron intensity of about 10% of the design bunch intensity, i.e. $2\cdot10^9$ positrons per bunch, is desirable for the auxiliary positron source.

Figure 1 shows the positron production as function of the drive beam energy for the case of an electron beam hitting a 0.4 radiation length thick Titanium target as foreseen for the undulator based positron source. An optimized target thickness (and possibly target material) could be realized by adding a second ring to the target wheel and move it transversely for the auxiliary source operation[1]. This option is not followed up here.

The capture optics to be used for the operation of the auxiliary source is optimized for the undulator operation. The undulator based source produces a beam with a smaller transverse momentum spread as a thick target conventional source and the optics is optimized for these conditions. (The optimum taper parameter of the adiabatic matching device following the target is 30 m^{-1} for the undulator based source, while it is typically about 60 m^{-1} for a conventional source.) The beam produced by electrons in the auxiliary source has also a small transverse momentum spread, since it is produced in a thin target. However, the average energy of the positrons is relatively high. The capture efficiency of

---

[1] The possibility to move the target wheel slowly in the transverse direction is also considered as an option to improve the target lifetime, see ref. 2.

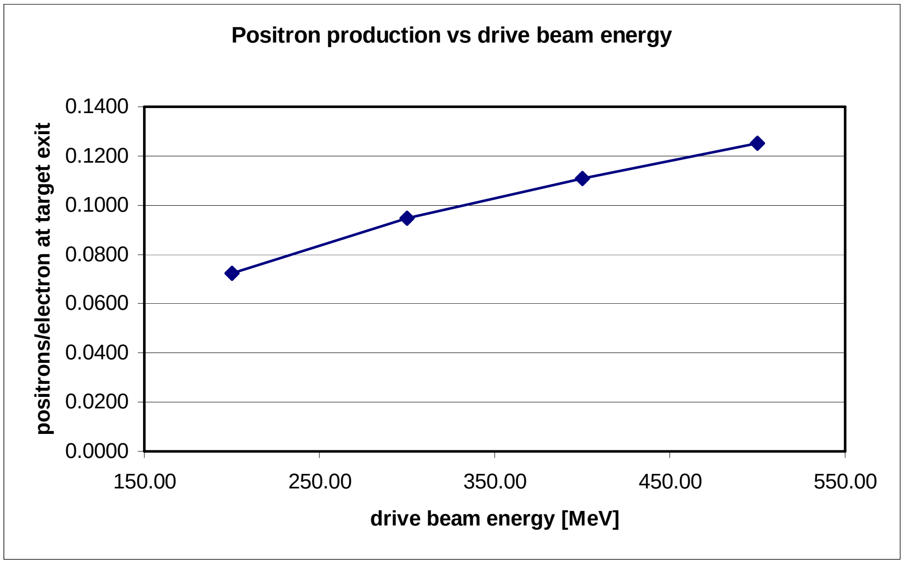

Figure 1: Positron production vs drive beam energy. The Electron beam hits a 0.4 radiation length thick Titanium target. The number of positrons is counted at the target exit.

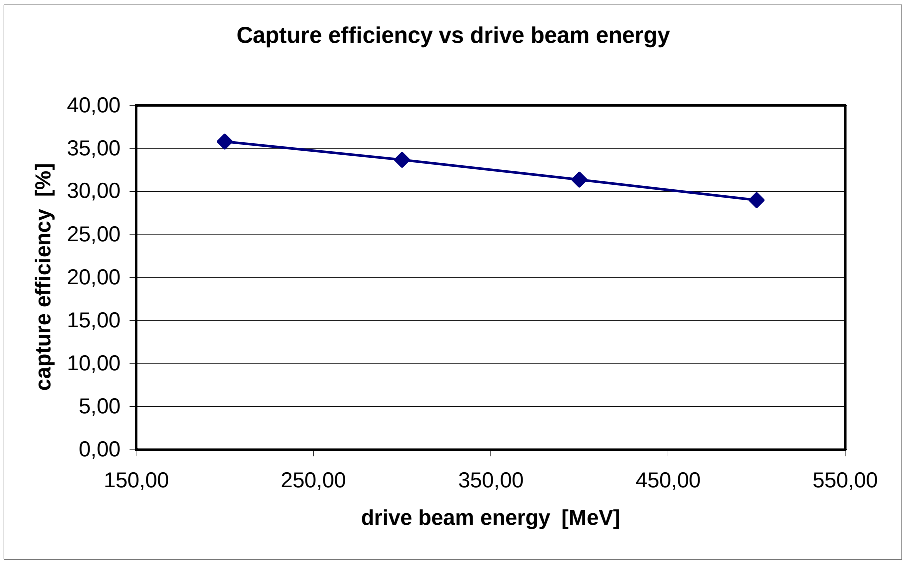

Figure 2: Capture efficiency vs drive beam energy. The positrons are captured in the capture optics designed for the undulator based positron source. Initial bunch parameters: $\sigma_{x,y} = 0.7$mm, $\sigma_z = 1.1$ mm. The usual cuts ($\varepsilon_x + \varepsilon_y \leq 0.08$ rad m and $\Delta E / E \leq 1\%$) have been applied.

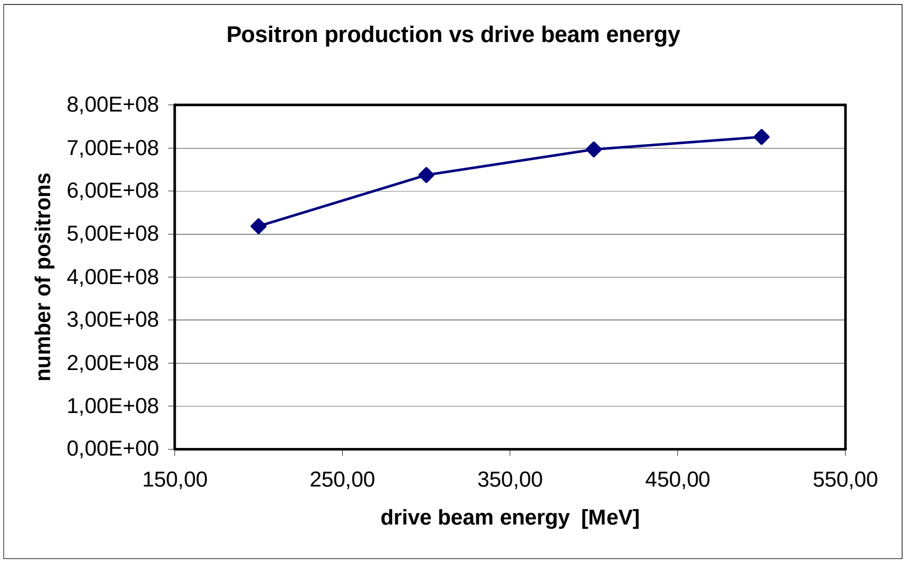

Figure 3: Positron intensity vs drive beam energy. The combined effect of the positron production and the capture efficiency is shown.

the positrons is ~30% for 500 MeV drive beam energy and increases when the energy of the drive beam is reduced as shown in Figure 2. For this calculations the optics as it has been used for the undulator based positron production have been used without modifications and the same cuts in the longitudinal and transverse phase space have been applied (see [3] for comparison and details of the optics). Except for a small difference in the final energy the beam parameters are hence the same for the undulator and the auxiliary source.

The increasing capture efficiency counteracts the reduced positron production at lower energies; hence the dependence of the positron production on the drive beam energy is weaker as suggested by Figure 1. Figure 3 shows the positron yield behind the capture section as function of the drive beam energy. The nominal bunch population of $2{\cdot}10^{10}$ electrons per bunch (3.2 nC) is assumed for the drive beam.

The positron intensity reaches of 3-3.5% of the design intensity for energies between of 250 and 400 MeV. A straight forward way to increase this to the desired values above 10% is to increase the bunch population of the drive beam by a factor 3-5. Heat load on the target and in the capture optics as well as beam loading in the electron injector can be controlled by increasing the bunch distance and reducing the bunch number (i.e. keeping the rf pulse length constant). The DC gun based design of the polarized electron injector will have a factor of 2 overhead concerning the electron production. A further increase might be difficult; however, with the integration of an unpolarized rf-gun a bunch charge of 10-15 nC can rather easily be realized[2]. The rf-gun can be integrated into the injector as sketched in Figure 4, so that the gun is placed directly in front of the superconducting module similar to the TTF injector design. The polarized guns and room temperature

---

[2] Bunch currents of up to 15 nC have been extracted at TTFI from the gun. The present gun design, optimized for lower emittances, has a smaller cathode area and some aperture limitations and is hence not suitable for high current tests.

sections can be added later in case that the e^-e^- or γγ operation are considered as upgrade options.

Table 1 lists not fully optimized simulation results for this TTF like injector operated at high bunch charge. Assuming a large cathode area and enlarged apertures in the section between gun and module the 15 nC can be transmitted without losses. The first cavity operates -95° off-crest, leading to a longitudinal bunch compression in the first section. With maximum cavity gradients of 30 MV/m a beam energy of 220 MeV can be reached with only one superconducting module.

The auxiliary source driven with this injector would deliver ~13% of the design bunch charge, i.e. $2.6 \cdot 10^9$ positrons per bunch, well within the dynamic range of the BPMs. A further increase of the production by increasing the energy or the electron bunch population may be considered. The latter option requires more detailed studies

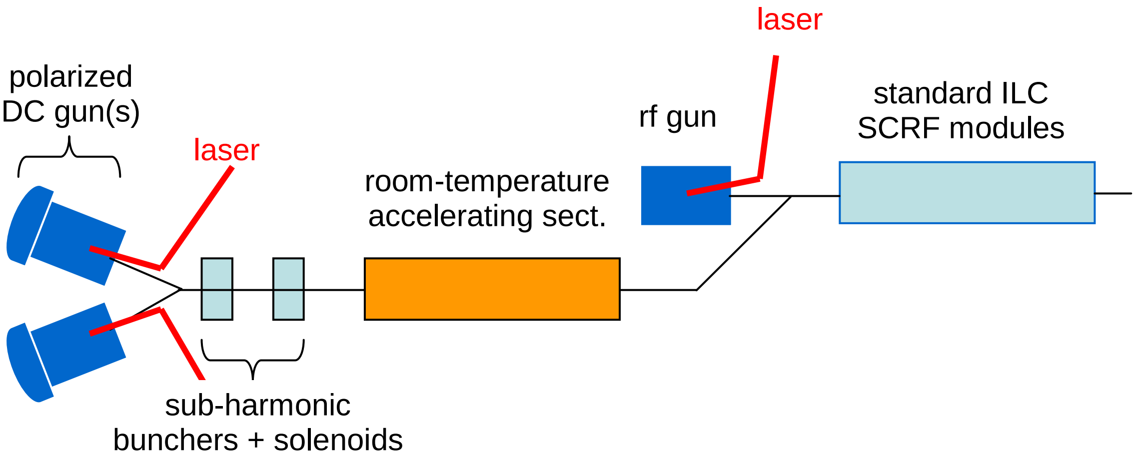

Figure 4: Polarized injector design with integrated rf gun for high current operation.

Bunch Charge	15 nC
Laser Parameters:	
transverse profile, flat-top	$\sigma_{x,y} = 3.5$ mm
longitudinal profile, Gaussian	$\sigma_t = 3.0$ ps
Beam Parameters at exit:	
energy	220 MeV
rms energy spread	140 KeV
rms bunch length	1.1 mm
transverse emittance	42 mrad mm

Table 1: Simulation results for the high bunch charge operation of a TTF like injector.

References

1. TESLA Technical Design Report, Part II, Mar 01, http://tesla.desy.de/new_pages/TDR_CD/start.html
2. W. Stein, “Conventional and Undulator Beam Target Thermal-Structural Analyses”, Workshop on Positron Sources, Daresbury, Apr. 05.
3. K. Floettmann, “Preparing the decision: Conventional versus Undulator based Source”, EUROTEV-Report-2005-015-1, Aug. 05.