ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-MOPMF084

THE PROGRESS OF CEPC POSITRON SOURCE DESIGN*

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Abstract

Circular Electron-Positron Collider (CEPC) is a 100 km ring e^+ e^- collider for a Higgs factory. The injector is composed of 10 GeV linac and 120 GeV booster. The linac of CEPC is a normal conducting S-band linac with frequency in 2856.75 MHz providing electron and positron beam at an energy up to 10 GeV with repetition frequency in 100 Hz. The positron source of CEPC is composed of target, flux concentrator, pre-accelerating section and beam separation system. The detailed design of positron source will be presented and discussed, meanwhile the start-to-end dynamic simulation results will be presented also in this paper.

INTRODUCTION

With the discovery of the Higgs particle at the Large Hadron Collider at CERN in July 2012, further research and measurement in Higgs is a very important issue for particle physics. Because the energy of Higgs is much lower than expected before, it is a big possibility to build a circular collider as a Higgs factory. In 2012, Chinese scientists proposed a Circular Electron Positron Collider (CEPC) in China at 240 GeV centre of mass for Higgs studies [1][2]. It could later be used to host a Super proton proton Collider (SppC) in the future as a machine for new physics and discovery.

The injector of CEPC is composed of linac and booster. The CEPC booster provides 120 GeV electron and positron beams to the CEPC collider and is in the same tunnel as the collider. The first part of the injector is a normal conducting S-band linac with frequency in 2856.75 MHz and provide electron and positron beams at an energy up to 10 GeV. The main parameters of the CEPC linac are shown in Table 1.

Table 1: Main Parameters of the CEPC Linac

Parameter	Unit	Value
e- /e+ beam energy	GeV	10
Repetition rate	Hz	100
e- /e+ bunch population		$>9.4\times10^9$
	nC	>1.5
Energy spread (e- /e+)		$<2\times10^{-3}$
Emittance (e- /e+)	nm	<120
e- beam energy on Target	GeV	4
e- bunch charge on Target	nC	10

The required bunch charge of electrons and positrons at linac exit is larger than 1.5 nC, considering enough allowance and high bunch charge potential, the bunch charge of the CEPC linac is designed as 3 nC. So the electron beam energy for positron production is 4 GeV with bunch charge 10 nC. The positron source is composed of a conventional positron target, Adiabatic Matching Device (AMD), 6 accelerating structure and chicane system. In this paper detailed design of positron source is presented.

PHYSICS DESIGN

A schematic layout of the positron source is shown in Fig. 1, which is composed of target, flux concentrator or AMD, 2 capture accelerating structure (blue), 4 pre-accelerating structure (orange) and chicane system. To achieve a 3 nC bunch charge positron beam, a 4 GeV primary electron with an intensity of 10 nC/bunch is designed. The average beam power is 4 kW at a repetition rate of 100 Hz.

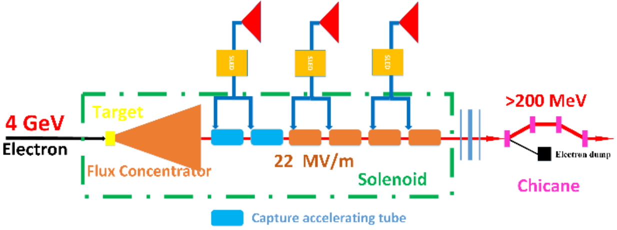

Figure 1: The layout of CEPC positron source.

Target

The simulation study on target design of positron source has been done by using G4beamline [3] and FLUKA [4]. The initial electron beam energy is 4GeV with rms beam size 0.5 mm. The positron yield at target exit was optimized by scanning the tungsten target thickness at different electron beam energy, which is shown in Fig. 2. According to the positron yield and energy deposition, the thickness of W target is adopted as 15 mm.

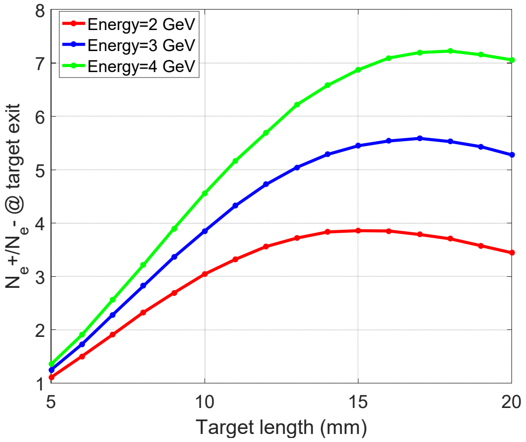

Figure 2: Positron yield with different target length and electron energy.

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* Work supported by NSFC (11705214)
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The cylindrical W target is embedded in the cuboid copper block, which can support and cooling the target. The energy deposition simulation results is shown in Fig. 3 and the total energy deposition is 0.784 GeV/e- in the case of 4 GeV electron beam, which means that the power deposition is about 784 W and the water cooling is necessary.

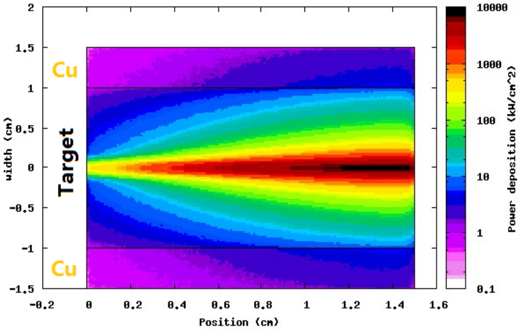

Figure 3: Energy deposition in the target.

AMD

The large transverse emittance of the positron beam emerging from the target is matched to the pre-accelerating section with an flux concentrator or AMD, shown in Fig. 4. The magnetic field is a pseudo-adiabatically changing solenoid field from peak 6 T to 0.5 T, which is a flux concentrator superimposed on a 0.5-T DC solenoid field, shown in Fig. 5. The beam with large divergence and small beam size emerged from target is transformed to small divergence and large beam size with AMD. The simulation results are shown in Fig. 6.

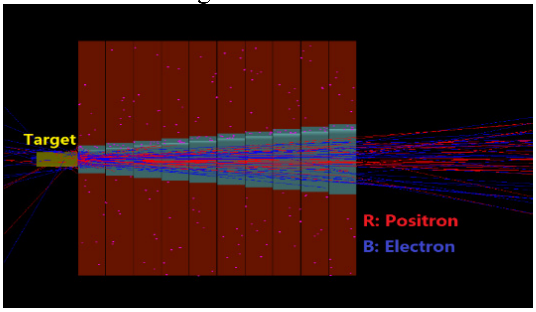

Figure 4: The layout of target and AMD.

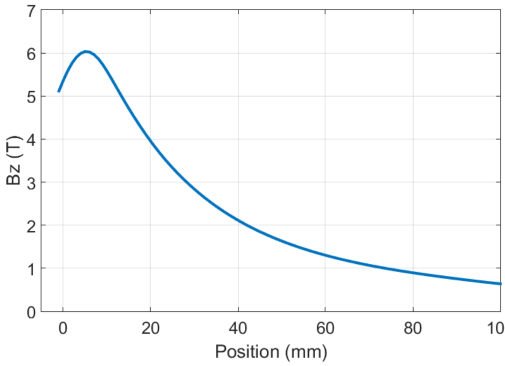

Figure 5: The magnetic field of AMD.

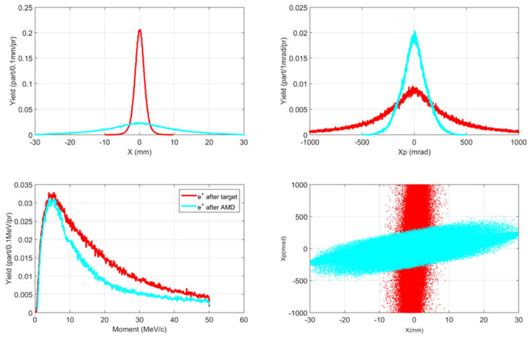

Figure 6: Beam transformation by the AMD.

Capture section

In this section one klystron drive two accelerating structure. Because of large beam size after AMD, larger aperture of capture accelerating structure is preferred for high capture efficiency. Higher accelerating gradient is preferred to accelerate positron beam to high energy as soon as possible. For the accelerating structure, the larger aperture means larger group velocity, the lower power utilization and accelerating gradient is smaller. Comprehensive consideration of positron capture efficiency, emittance control and accelerating structure design, the aperture of accelerating tube is chosen as 25 mm. Figure 7 shows the positron yield at the second capture accelerating structure exit with different accelerating gradient and input phase corresponding to RF phase. There are two phase range where have higher positron yield: deceleration mode and acceleration mode. According to positron yield and consideration on beam energy, the accelerating gradient is chosen as 22 MV/m.

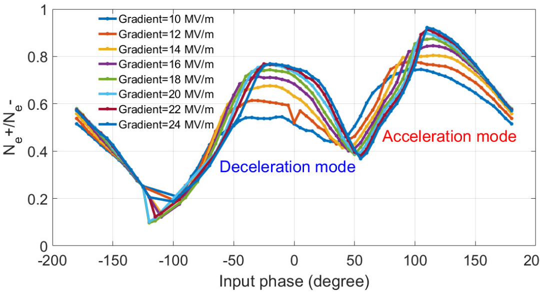

Figure 7: Positron yield at the second accelerating structure exit with different accelerating gradient and phase.

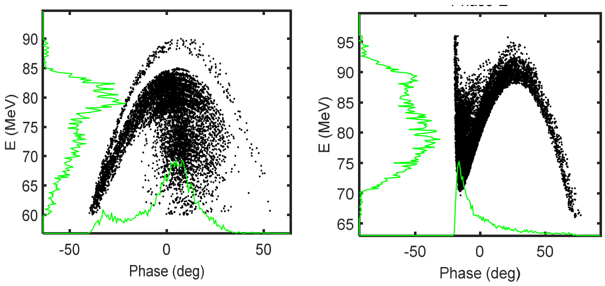

Figure 8: Beam distribution at the second accelerating structure exit, left is deceleration mod and right is acceleration mod.

The beam distributions of deceleration mode and acceleration mode at the capture accelerating structure exit are shown in Fig.8. From the simulation results acceleration mode have more compact phase spectrum. Considering the energy spread of linac is mainly decided by bunch length, the acceleration mode is adopted in the simulation. The deceleration mode is also possible in the operation of linac, same as KEKB.

Pre-accelerating section

In the pre-accelerating section there are four accelerating structure to accelerate positron beam larger than 200 MeV. The accelerating RF phase for the two modes have been scanned, which is shown in Fig. 9. From the simulation results, for deceleration mode the rf phase of pre-accelerating structure can set same as capture section and fore acceleration mode there is phase shift about 25°.

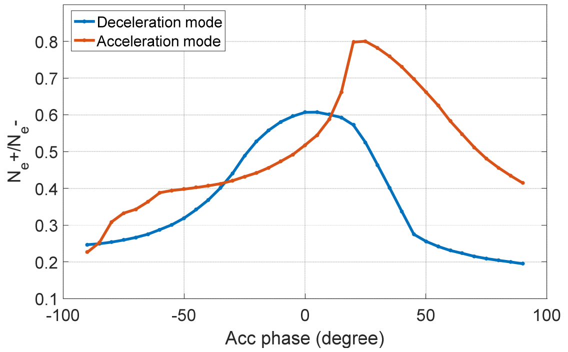

Figure 9: Positron beam population with different accelerating rf phase.

Chicane system

The chicane system is designed to separate the accompanying electron to beam dump. The chicane is achromatic. The four dipoles are the identical rectangular type and can be driven by one power supply.

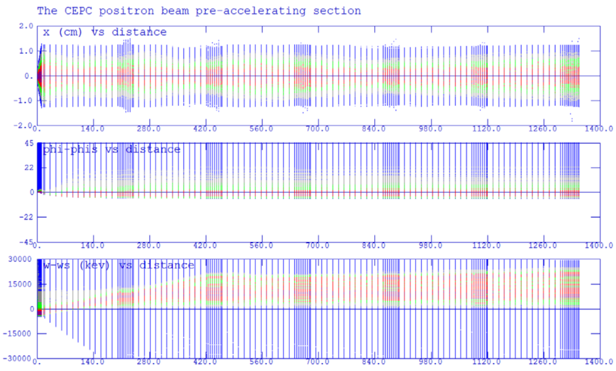

Figure 10: Beam envelope from target exit to pre-accelerating section exit.

END-TO-END SIMULATION

In the simulation the accelerating mode is adopted. The envelope from target exit to pre-accelerating section exit is shown in Fig. 10. The distribution at pre-accelerating section exit is shown in Fig. 11, where the energy cut off condition is from 235 MeV to 265 MeV and the phase cut off condition is from -6° to 14°. In this cut off condition the positron beam yield (Ne^+/Ne^-) is about 0.55, which can meet the bunch charge requirement.

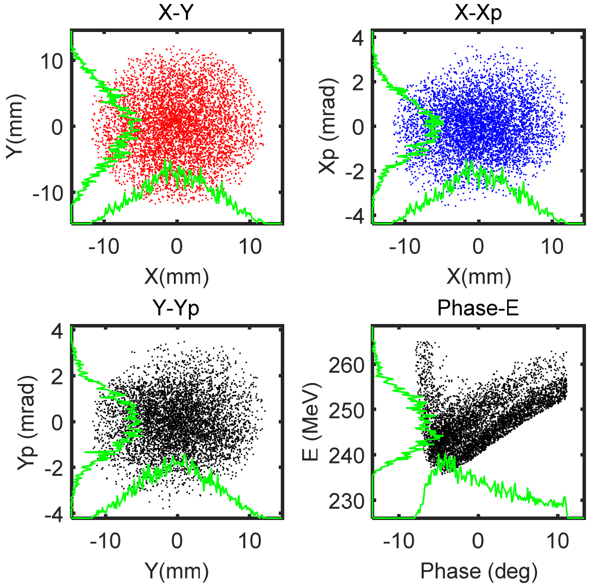

Figure 11: The distribution at pre-accelerating section exit.

CONCLUSION

CEPC is a 100 km ring e+ e- collider for a Higgs factory. The injector is composed of 10 GeV linac and 120 GeV booster. In this paper the design of positron source and pre-accelerating section is presented and discussed detailed. The positron yield at pre-accelerating section is about 0.55.

ACKNOWLEDGEMENTS

The authors would like to thank all the CEPC group members for their valuable suggestions and comments.

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