ANALISYS OF POSITRON FOCUSING SECTION FOR SPring-8 LINAC

A. Mizuno, S. Suzuki, H. Yoshikawa, T. Hori, K. Yanagida, H. Sakaki, T. Taniuchi, H. Kotaki and H. Yokomizo, JAERI-RIKEN SPring-8 Project Team, Kamigori, Ako-gun, Hyogo 678-12, Japan

Abstract

In the SPring-8, positron beams will be used and generated in the linac. In this paper, simulations and experiments of a test apparatus for the convertor are described. Results of simulations are qualitatively coincident with that of experiments, and from simulation results, an electron/positron conversion efficiency of 0.5% is obtained at the end of the convertor, with a feasible design of the convertor system. A future plan of super-conducting magnet system for the convertor is also mentioned.

I. INTRODUCTION

We are planning to use positrons to avoid ion-trapping and make a beam-lifetime longer in the SPring-8 Storage Ring. The positrons will be generated in the SPring-8 Linac at 250MeV section, and accelerated up to 900MeV at the end of the Linac. For reducing an injection time to the Storage Ring, we have to achieve high conversion efficiency as possible.

In order to design an electron/positron convertor (target and focusing system) for the Linac, we constructed a test apparatus mounted with the JAERI Linac at Tokai Establishment, JAERI, and obtained energy spectrums of the generated positrons with various parameters of focusing system. Also, we developed a simulation code of tracking particles in the positron focusing section. Results of simulation and experiments are mentioned, and our design of the converter are discussed.

II. TEST APPARATUS AND SIMULATION CODES

The test apparatus at Tokai Establishment is shown in Figure1, which consists of a removable tungsten target (insert or pull out), a focusing section (a pulse solenoidal coil, a DC1 solenoidal coil, a DC2 solenoidal coil, an accelerator structure, and a quadrupole magnet), and a measurement section (an energy analyzing magnet and a Faraday-cup). Electrons bombard to the target with an energy of about 90MeV. Generated positrons are focused and accelerated up to ~35MeV in the focusing section.

The simulation consists of two codes. One is EGS4 and another is our original tracking code. EGS4[1] is a Montecalro code. It calculates positron production at the surface of the tungsten target. Given parameters are injected electron position, injection angle to the target (we assume that all electrons bombard to the target perpendicularly), and electron energy on the entrance of the target. Output parameters of this code are position, extracted angle from the target, and energy of positrons which are provided to the tracking code as initial conditions.

The tracking code is used fourth-ordered Lunge-Kutta method and tracking positrons from the target to the end of the focusing section. we assume that there are uniform electric field in the accelerator structure section, and calculated magnetic fields are given in the coil sections.

In the test apparatus, variable parameters are magnetic field of focusing section and rf power to the accelerator structure which are important information as design parameters. And these can be also variable in the tracking codes. So we can compare the experiment results with the simulation's one.

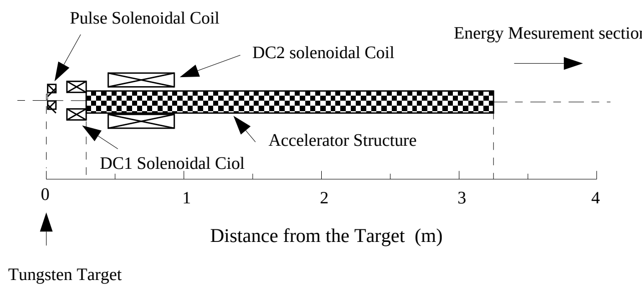

Figure. 1. Outline of the test apparatus

III. RESULTS OF EXPERIMENT AND SIMULATION

Figure2 shows representative data of simulation and experiment. These are energy distributions of positrons at the final point of the focusing section. In Figure2, variable parameter is current of the pulse solenoidal coil. Parameters of the DC1 and the DC2 coils and rf power for the accelerator structure are constant. Magnetic field distribution is shown in Figure3, which corresponds to the case of bottom graph in Figure2. TABLE.1 shows experiment and simulation parameters of Figure2.

From the Figure2, figure of distribution in simulation data is qualitatively coincident with that in experiment data. Further more, when the other parameters are varied, DC1 or DC2 coils, they are also in agreement qualitatively. Other data can be referred in ref.[2].

In the Figure2, a lower side peak in the energy distribution shifts to right hand side as pulse solenoidal current increases. From this, pulse solenoidal coil has selectivity of positron energy. Other coils don't have such contribution[2]. This is important issue for designing the focusing section.

A conversion efficiency of produced positrons at the end of the focusing section against injected electrons is obtained of 0.077% in Figure2 simulation data, where produced positrons energy is 0~50MeV on the surface of the target. Within the limited energy, the peak±1MeV, the efficiency is 0.018%.

In the experiment data, energy resolution at the peak is about ±1MeV, and an efficiency of positron current at the peak

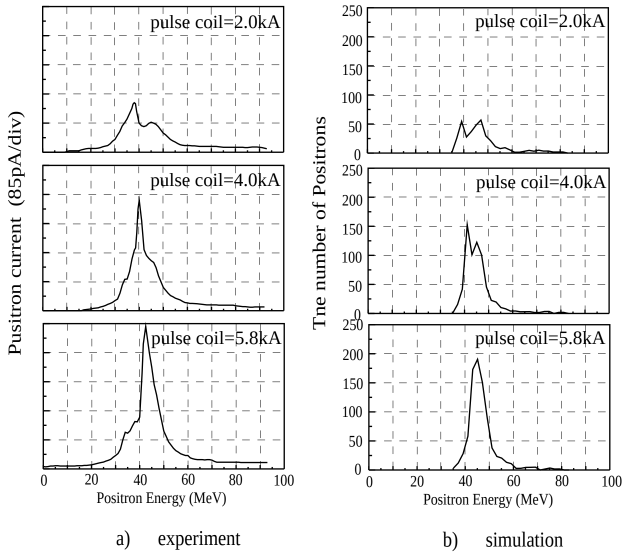

Figure. 2. Energy distribution of Produced positron

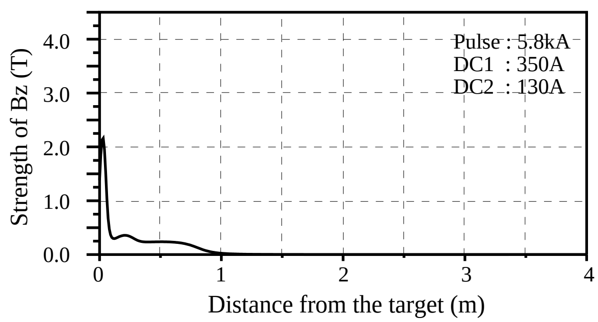

Figure. 3. Magnetic field distribution of the test apparatus

TABLE.1 parameters of experiment and simulatoin

	EXPRIMENT	SIMULATION
Target	Tungsten	Tungsten
Target radius	10.0mm	10.0mm
Target thickness	6.0mm	6.0mm
Ingected electron	(current)	(number of histries)
	150nA(average)	1,026,000
Injected electron energy	90MeV	90MeV
Repetition rate	5pps	--
Pulse width of electron current	1&Lsec	--
Energy gain of positrons	33.1MeV	33.1MeV
Radius of injected beam	--	1mm

against injected electron current is 0.01%, which is comparable with simulation data of 0.018%. So experiment efficiency is 55% of simulation data. Reason of this is not cleared to us enough, but all other data show around this rate.[3]

IV. THE CONVERTOR OF THE FOCUSING SECTION FOR THE SPring-8 LINAC

The positron focusing section is now under construction. It's outline is shown in Figure4. Capable magnetic field will be update in Figure5. Produced positrons can be accelerated up to about 50MeV. In this field distribution, positrons with energy of 20MeV at the surface of the target rotate half times in the section of the pulse solenoidal coil, and will be selected by the pulse solenoidal coil. Some topics for designing this section are mentioned below. From simulation data of tilting pulse solenoidal coil, the efficiency was appeared to decrease a lot. When the pulse solenoidal coil tilt 50mrad, the efficiency will become to half of non tilting case[4]. So the pulse solenoidal coil has adjustable mechanism for tilting. The efficiency increase were observed in the simulation when magnetic field distribution of DC2 solenoidal coils is not uniform[4], so 3 power supplies will be prepared independently to

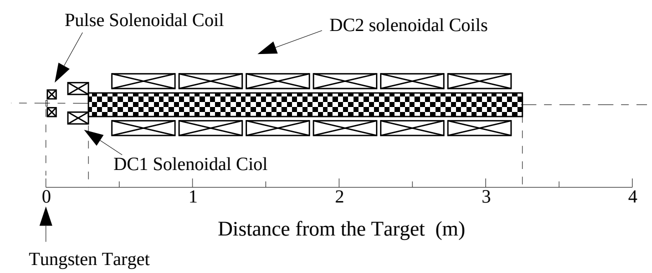

Figure. 4. Outline of the focusing section for the SPring-8 Linac

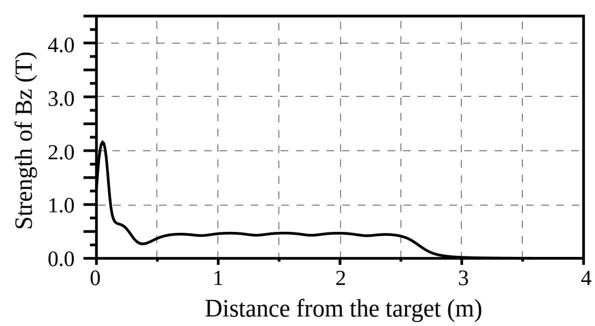

Figure. 5. Capable magnetic field distribution of the SPring-8 Linac

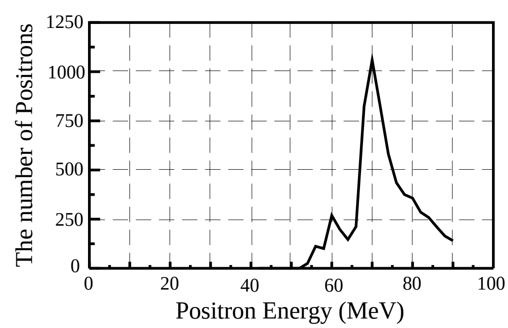

Figure. 6. Energy distribution of the SPring-8 convertor

drive 6 DC2 solenoidal coils. So we can arrange various magnetic field distribution and strength within Figure.4. Figure.6 shows a simulation data with a feasible design of convertor. In this case, produced positrons are accelerated to 40MeV. (Its efficiency is better than that of 50MeV case.) The magnetic field strength in the DC2 solenoidal coil section is increase step by step along beam line. The efficiency of Figure.6 is 0.5% within the limited energy, the peak±5MeV. The actual conversion efficiency will be predicted of around 0.3% from previous rate and Figure.6.

V. PLAN FOR SUPER-CONDUCTING MAGNET

Further studies of super-conducting magnets are mentioned below. In this system, maintenance-free refrigerated super-conducting magnet is used instead of liquid helium type.[5] Figure7 shows capable magnetic field distribution with new type superconducting magnet system. In this system, a DC coil is available instead of the pulse solenoidal coil. But keeping superconductivity against incident power to the coils, which are provided by neutrons, electrons, positrons or photons, is severe problem. Figure8 shows EGS4 simulation data of distribution of the incident power to the wall of the coils with full power injection to the target. (except for contribution of neutrons) In the SPring-8 Linac, full injection power is estimated to be 7.2kW. Parameters of full power injection are seen in TABLE.2. In this case, an inside diameter of the DC coil will be made larger compared with normal pulse solenoidal coil, and a lead will be inserted between the target and the coil. But the incident power to the pulse solenoidal coil part of 16W is about one order lager than the level of keeping super-conductivity. So this system can not to be acceptable this time, it is one of a theme in the future.

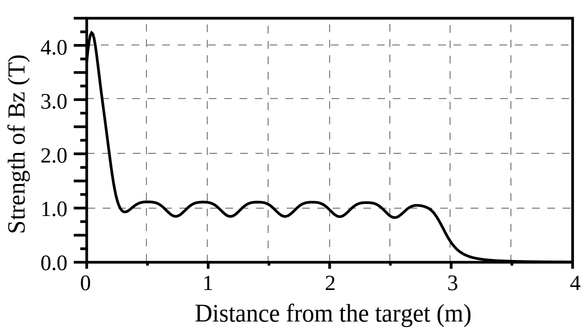

Figure. 7. Magnetic field distribution for the future plan

TABLE.2 Parameters of full power injection to the target

Injection electron energy	300MeV
Injection beam pulse width	40nsec
Injection beam pulse current	10A
Pulse repetition rate	60pps
Injection power	7.2kW

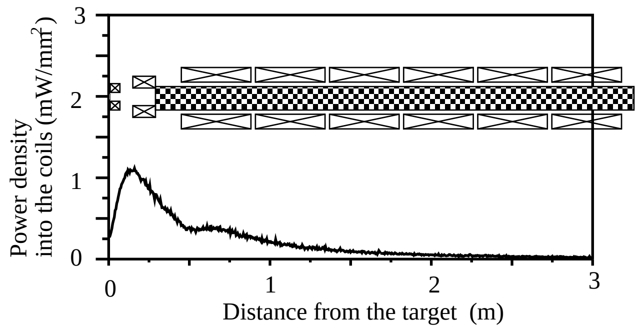

Figure. 8. Incident heat power to the solenoidal coils

VI. CONCLUSION

Simulations and experiments of the electron/positron convertor for the SPring-8 linac was compared. In these data, simulations were qualitatively coincident with experiments, but conversion efficiency of experiment data was obtained to be about 55% of simulation's one. We obtained the conversion efficiency of 0.5% for the actual SPring-8 convertor by simulation. With consideration of above ratio, the actual conversion efficiency will be predicted of around 0.3%.

Reference

[1]Walter R.Nelson, Hideo Hirayama, and David W. O. Rogers, SLAC Report-265, (1985)
[2]A. Mizuno, et al., Proc. of the 9th Symp. on Accelerator Science and Technology, 122 (1993)
[3]A. Mizuno, et al., JAERI-Research 94-021 (1994)
[4]A. Mizuno, et al., JAERI-M 93-030 (1993)
[5]T. Minato, et al., MITUBISHI DENKI GIHO, Vol.68,No.9, 51 (1994)