BEPCII INJECTOR DESIGN CONSIDERATIONS

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Abstract

BEPCII will adopt double ring scheme with single beam current of 1.1A. The fundamental requirements to injector linac are 1.89GeV positron energy, 50mA/min injection rate and very stable beam with energy spread less than ±0.6%. For the energy issue, 50MW klystrons will be utilized to replace homemade klystrons. For the beam current issue, we're going to use a new high current electron gun to increase bombarding beam current, and use a new positron source to improve positron capture efficiency. At the same time, a SLAC 5045 klystron will be used at the second RF power station (K_2) and the correlated RF structures will be also replaced so as to increase bombarding beam energy from 140MeV to 240MeV.

1 INTRODUCTION

BEPC injector is a 1.3 GeV electron linac, which was built in 1986 and has been in service for almost 15 years. The main parameters at linac end are energy of 1.3GeV, positron beam current of 4~5mA, bunch width 2.5nS and repetition rate 12.5Hz. The electron beam energy for positron production is 140MeV and routine positron injection rate into the ring now is about 3mA/min. BEPCII, to be upgraded with a luminosity of $3.8\times10^{32}cm^{-2}s^{-1}$@1.55GeV, has been approved by the Central Government in principle as future development of high energy physics in China. The luminosity is almost two orders of magnitude higher than that of existing machine BEPC. It needs full energy injection at 1.55GeV(later on at 1.89GeV), and a positron injection rate of 50mA/min. Table one shows the main parameters of BEPCII injector. Among these parameters, the positron injection rate is very demanding, which is 17 times as high as that of BEPC routine operation. We're going to take following measures to get the needed filling rate:

- Increasing repetition rate from 12.5Hz to 50Hz ×4
- Increasing bombarding electron energy from 140MeV to 240MeV ×1.7
- Improving positron yield at the linac end from 1.4 to 2.7% $e^+/(e^-\times GeV)$ ×1.9
- Two-bunch injection ×1.6

Technically, 1.89GeV positron beam injection is not difficult for 200-meter long linac. If we use 50MW klystrons (replace home-made 30MW klystrons), and let them stably work at ~35MW, it'll be very easy to increase beam energy from 1.3GeV to 1.89GeV.

Tab.2.12.1 Parameters of BEPCII injector

Energy	1.89	GeV
Energy spread	≤±0.6	%
Positron current at the end of linac	28.8mA	1.8×10^{8}
Gun (EIMAC Y796) DC high voltage Bunch current Macro bunch width Repetition rate Macro bunch separation	 120~15 0 10A 1.0 50 56.02	 kV 6.25×10^{1} 0 ns Hz ns
Positron system Target (W) e^- energy on target e^- current on target Peak field of FLUX DC field of solenoid e^+ yield at solenoid end e^+ yield at the linac end	 8 240 4.5A 4.5 0.5 0.038 0.027	 mm MeV 2.8×10^{10} T T $e^+/e^-\cdot GeV$ $e^+/e^-\cdot GeV$
e^+ transfer and injection efficiency	30	%
e^+ number injected into ring in 1 minute	2.6×10^{11}	51mA

2 BEAM CURRENT ISSUE

2.1 Electron gun

BEPC cathode is EIMAC Y824. For 2.5ns pulse at 80kV anode voltage, the limited emission current is 5A. Like other high luminosity colliders, BEPCII needs much higher intensity and better quality electron gun system. Y796 [1] has been proved to be a good candidate for higher emission cathode. In the space charge limit region, the maximum anode current is predicted to be 12A at an injection voltage of 160kV. Figure 1 shows the gun optics calculated by the electro-trajectory program of W.B.Hermannsfeld [2]. In the calculation the current was assumed to be 12A, which is the actual value of a short-pulsed beam (2ns). The calculation predicts a perviance of 0.19μA/$V^{3/2}$ and an emittance of 1.4×10^{-2} π(m_0c·cm).

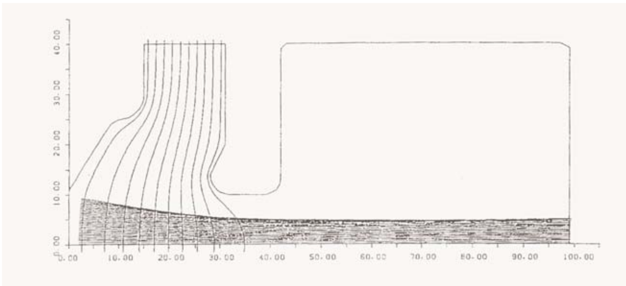

Figure 1 Computer plot of the gun optics at 160 kV showing equal-potential surfaces and the beam-focusing pattern. Shaded area denotes the electron beam. The emission current is assumed to be 12A.

2.2 Electron energy for positron production

Figure 2 shows the schematic diagram of the BEPC positron production system. There are four klystrons and eight RF acceleration structures. The pre-injector consists of an EIMAC Y824 electron gun, an S-band pre-buncher, a buncher and the first RF acceleration structure A_0 driven by the HK1 klystron (30MW) K_1. Second klystron K_2 with SLED drives four acceleration tubes to produce the required energy for positron production. BEPC's design electron energy for positron production was 150MeV, while BEPCII is 240MeV. For the RF power source, we can use SLAC 5045 to replace the home-made HK1 klystron. We have already developed a 150MW modulator for 5045 tube and used the new RF power source in klystron gallery for previous BEPC linac energy upgrades.

Since early operation we've faced some badly sparking problems in the RF structure of this section. When we installed BEPC 250MeV section in 1986, the high power dummy loads were not properly baked and the degassing contaminated the whole RF structures. Since the new accelerating gradient will be about 20MeV/m, we have to replace the eight existing tubes with new ones.

2.3 New positron production system

BEPC positron source is also shown in Figure 2. It consists of a ϕ10×6 mm tungsten target, a two-coil pulsed solenoid used as flux concentrator with peak field of 2.6T, a 9m long DC solenoid with the field of 0.35T, three SLAC constant gradient acceleration structures, and power supplies, etc. Built in 1986, the maximum positron beam was about 9mA at linac end with electron beam power of 150MeV and 2.5A. The positron yield was 2.4%. But the routine positron beam is only 4~5mA now, presumably because the system or some components were suffering from aging problems and couldn't work at their design values. Some of the early design considerations were also dissatisfactory. For example, steering coils couldn't efficiently compensate the 0.5Gs dipole field of the DC solenoid, pulsed solenoid had the potential problem of break, the system was uneasy for maintenance, etc. All these problems are now becoming the bottleneck for the BEPC operation and the further development. BEPCII will use a new system.

As acknowledged, SLC/PEPII [3] and KEKB [4] positron sources exemplify the latest positron production technology. The main difference of them is the matching device. KEKB positron source uses QWT as matching device. DAΦNE [5] positron converter is heavily based on the SLAC scheme. The capture system is essentially composed by a tapered field DC solenoid, with a peak of 1.2T, and by a pulsed coil, the SLAC design flux concentrator, which generates a solenoid field that drops adiabatically from the peak of 3.7T to zero in about 12cm.

BEPCII linac will be very similar to the Frascati one. Both are inline machines with almost the same electron beam power of 250MeV and 4A for positron production. We're going to refer to the DAΦNE positron converter as well as DC focusing system, but engineering design will be a little different, which depends on the state of art for manufacture. Figure 3 shows the EGS4 and PARMELA simulation results for both BEPC and BEPCII positron sources. Square curve is BEPCII positron yield as a function of electron beam size on target, while diamond curve and triangle △ of 1.6%e^+/(e^-·GeV) are for BEPC design and present value separately. So if we increase DC field from 0.35T to 0.5T, the positron yield can be increased about 70% from 3.2% to 5.5% e^+/(e^-·GeV) at the end of solenoid with electron beam radius of 2.5mm. The figure also shows the electron beam size makes great contribution to positron yield. Our goal is a beam radius of less than 1mm.

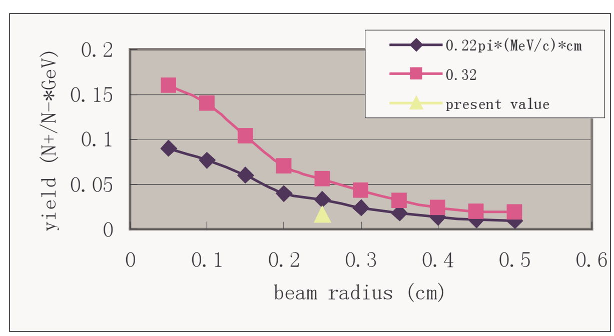

Figure 3 Positron yields as functions of electron beam radius

3 TWO-BUNCH INJECTION

BEPC II RF frequency has been chosen as 499.8MHz, and linac frequency is 2856MHz. So the common frequency is 17.85MHZ(2856/160, 499.8/28). The minimum bunch space is 56.02ns for synchronous acceleration. According to KEKB linac experience, two-bunch injection is possible, but not an easy job. The main issues are under investigation, such as two-bunch generation, acceleration and bunch selection for injection etc.

Another multi-bunch injection schemes are also possible since BEPCⅡ longitudinal acceptance is about 1ns. Minimum bunch gap of 8.05ns is exactly synchronized for linac, and not too bad for the ring. In this case, two-bunch mode is much easier, and three-bunch mode is possible. The big issue is how to make them equally accelerated.

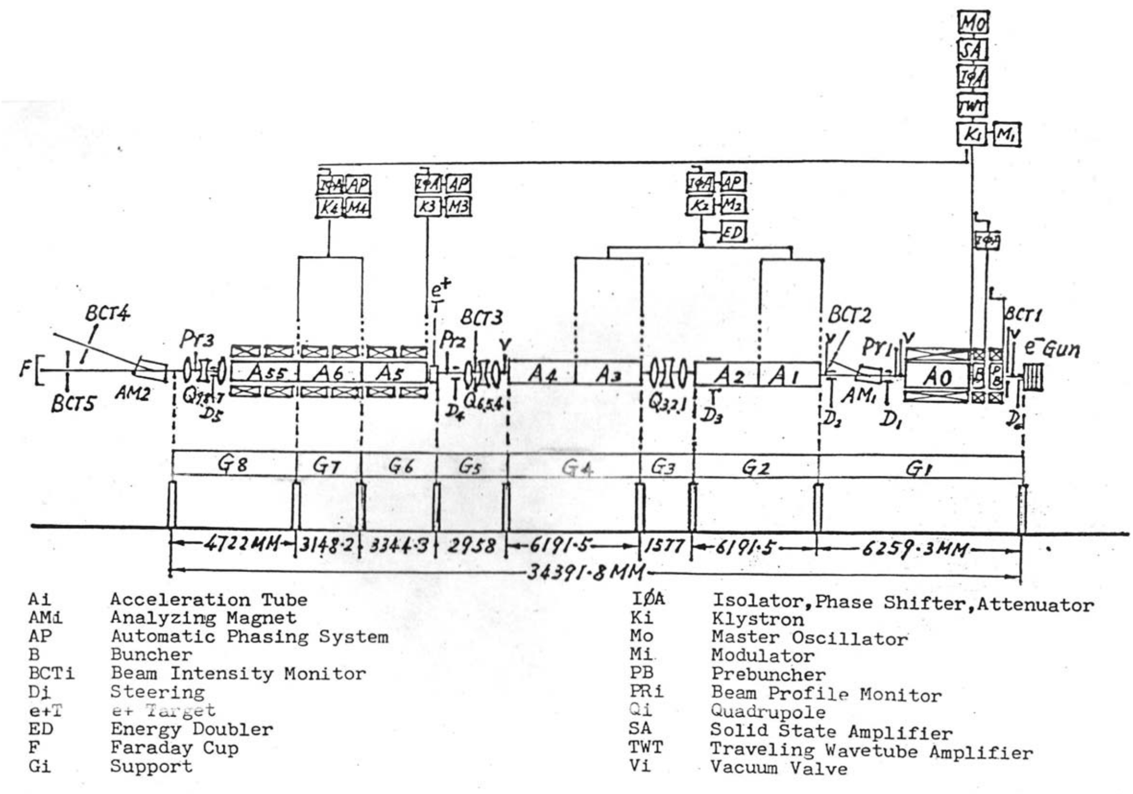

Figure 2 The schematic diagram of the BEPC 250MeV section.

4 RF POWER SOURCE

For the SLAC type RF structure, the energy gain for each standard section of 4 accelerator tubes driven by one klystron can be expressed as

$$\Delta E = 20M[(1-\delta)P]^{1/2} \quad ,$$

where M is the multiplication factor of SLED, δ RF transmission lose from klystron to accelerator tube, P the output power of klystron. Usually δ is about 5%. In order to have the linac worked stably at 1.89GeV, the output power of each klystron will be 35MW with SLED. We're going to use 45 or 50MW klystrons and make some modifications on old modulators for these new tubes.

The existing 80MW modulators were designed for 30MW klystrons. The peak beam voltage and peak beam current are 265kV and 290A, respectively. We can use 1:15 beam transformer to get the required peak beam voltage and current. DC power sources for modulators also need to be improved, considering repetition rate 50Hz of operation with a safe margin. Another important issue for modulator development is the stability. ±0.6% energy spread of linac beam requires that modulator beam voltage stability, including pulse-to-pulse jitter and long-term shift, be less than ±0.1%.

REFERENCE

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