STATUS OF VEPP-5 INJECTION COMPLEX

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Abstract

VEPP-5 Injection Complex was designed as a powerful source of intense electron and positron bunches at the energy of 510 MeV. Now Complex is very close to start full scale commissioning. The most important subsystems of Injection Complex (high intensity driving electron linac and positron production system) have been put in operation at designed parameters. The results of positron production system commissioning are presented in this paper.

INTRODUCTION

VEPP-5 Injection Complex consists of 270 MeV driving electron linac, 510 MeV positron linac and dumping ring. Both linacs are based on four accelerating modules, each one feeds by one SLAC klystron (5045). Two first modules have three accelerating structures and second two — four structures. Both linacs can operate at 50 Hz repetition rate. Dumping ring stores and cools down both electron and positron beams. It is equipped by 50 Hz injection system. Designed parameters of VEPP-5 Injection Complex are presented in Table 1. At the parameters listed above VEPP-5 Injection Complex will be able to cover all needs of BINP e^+e^- colliders (VEPP-4 and VEPP-2000) for nearest future. Only with new injection complex these colliders can reach their maximum luminosity.

Table 1: Parameters of Injection Complex.

Beam energy (MeV)	510
Max. number of electrons in the bunch	$2{\cdot}10^{10}$
Max. number of positrons in the bunch	$2{\cdot}10^{10}$
Energy spread in the bunch (%)	0.07
Longitudinal bunch sigma (mm)	4
Vertical emittance (mm mrad)	0.005
Horizontal emittance (mm mrad)	0.023
Dumping times vert./horis. (ms)	17/11
Extraction rate (Hz)	1

STATUS OF VEPP-5 INJECTION COMPLEX AND COMMISSIONING PLANS

Assembling of dumping ring is finished. Vacuum, RF and injection systems have been tested at nominal parameters. Dipole magnets and quadrupoles of the ring and injection channels are connected to power supplies and passed through short term tests. Beam diagnostic electronics and software are under testing now. Also the injection system of dumping ring is successfully passed through tests at nominal parameters. Practically dumping ring is ready now for commissioning.

Figure 1: Linear accelerators.

Figure 2: Damping ring.

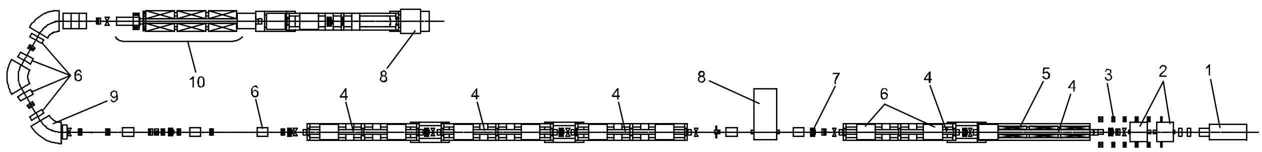

Figure 3: Part of injector complex is in operation now: 1 — electron gun, 2 — sub harmonic bunching system, 3 — focusing coil, 4 — accelerating structure, 5 — solenoid coil, 6 — quadrupole lens, 7 — corrector, 8 — spectrometer, 9 — bending magnet, 10 — positron production system and first accelerating structure of positron linac.

Driving electron linac and positron production system with first accelerating structure for positrons was successfully tested at nominal parameters and are ready for operation. The production of third accelerating module is practically finished. It will be ready for commissioning in November 2006. Third module allows to accelerate electrons up to 510 MeV and to provide the commissioning of dumping ring with electrons. It can be started in December 2006. Fig. 1 represents the picture of electron (right) and positron (left) linear accelerators placed in the same hall. Fig. 2. shows the picture of dumping ring. Vertical injection and extraction for electrons can be seen at the left part and for positrons – at the right.

RESULTS OF POSITRON PRODUCTION SYSTEM COMISSIONING

The commissioning of positron production system was held on the basis of two equal (from RF point of view) accelerator modules. Each one consists of 5045 SLAC klystron with power compression system (SLED type) and three constant impedance travelling wave accelerating structures. The first accelerating structure of the module utilises a half of the total power and each of two others — a quarter. Structures are identical and have the length of 3 m. The energy gain of the module at nominal klystron power (68 MW) is 180 MeV. These modules comprise also focusing magnetic system and beam diagnostic. 270 MeV electron linac includes first accelerating module and two quarter-powered structures of the second module. Third structure of the second module is placed after isochronous U-turn and used to accelerate positrons. Temporal positron beam diagnostic line follows the first positron accelerating structure and simulates the acceptance of further positron linac. The isochronous achromatic U-turn precedes the quadrupole triplet, which focus an electron beam on the positron production target. The beam profile monitors along the U-turn provides the beam energy and energy spread measurements. In order to measure the beam energy spectrum and the total charge at the output of the second accelerating structure of electron linac, a 180° spectrometer with sectional Faraday cup of full beam absorption was used. This device enables to measure the energy spectrum and the bunch charge with 2% accuracy. Additional Faraday cup is placed before the positron production target able to measure the charge of driving electron bunch.

The VEPP-5 preinjector electron accelerator can work both at the single bunch and the multibunch modes. Single bunch mode is a basic one for the Injection Complex operation with electron-positron colliders in BINP (VEPP-4 and VEPP-2000). In fact, the electron beam of 200 kV energy, 4 A current, and 2.5 ns width produced in the electron source should be almost 100 times compressed in the longitudinal direction. So that the pike current in the bunch and the bunch length should be 400 A and 6 mm, respectively. The compression occurs in two cavities, which operate at the 16^{th} RF subharmonic (178.5 MHz) of the accelerator main operation frequency (2856 MHz). The maintenance of the transverse beam size within a given range is ensured by the increasing value of a magnetic field in the longitudinal direction. The stable operation of accelerator in a single bunch mode requires steady amplitudes and phases for all elements of RF system. To control the bunch structure and bunching efficiency an electron beam probe [1] was developed and installed on the electron linac. The operation of this non-destructive beam diagnostic tool is based on scanning of a thin low energy electron beam in the electromagnetic fields of a short relativistic bunch. This device allows to measure the accelerated charge in each bunch of the train as well as to control relative transverse bunch positions and sizes. This online diagnostic tool helps a lot to maintain proper stability of the regime with intense single bunch. The scheme of driving electron linac and positron production test bench is presented at Fig. 3.

VEPP-5 Injection Complex positron source utilizes the conventional scheme of positron production, where positrons are collected from the electromagnetic shower produced by high energy electrons in heavy metal target. This target has an optimum length, which depends upon the energy of electrons. Practically optimum target length corresponds to the maximum brightness of outgoing positron beam. This maximum can be reached at less then 1 mm transverse size of driving electron beam on the target. The following Table 2 contains the key parameters of VEPP-5 positron source:

Table 2: Parameters of positron production system.

Electron beam energy (MeV)	270
Number of electrons in the bunch	1.8 10^{10}
Number of captured positrons	5 10^{8}
Nom. field in matching device (T)	7
Max. field in the solenoid (T)	0.5
Energy gain in first acc. struct.(MeV/m)	25
Max. repetition rate (Hz)	50

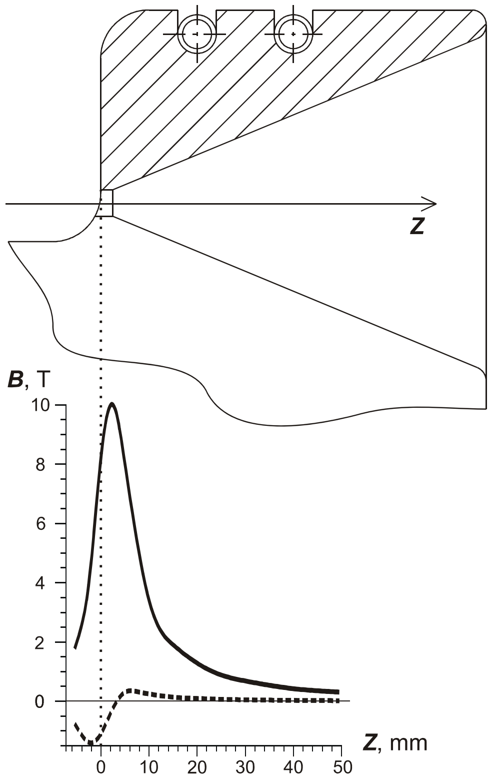

Figure 4: Results of magnetic measurements for matching device of VEPP-5 Injection Complex: upper curve — longitudinal magnetic field on the geometrical axis of the device, lower curve — transverse component of magnetic field on the geometrical axis Z.

Initial part of positron linac is usually immersed into uniform longitudinal magnetic field. It helps to enlarge the capture of positrons. But nevertheless the phase space footprint of positron beam at the exit from the target is not properly matched with further solenoid acceptance. This is why the special matching device is very desirable between target and solenoid of the first accelerating structure. It helps to increase the number of captured positrons (at least few times). In general this device should increase the transverse positron beam size and decrease angles. In other words it works as an achromatic focusing lens. Fig. 4 represents the dependance of longitudinal and transverse components of pulsed

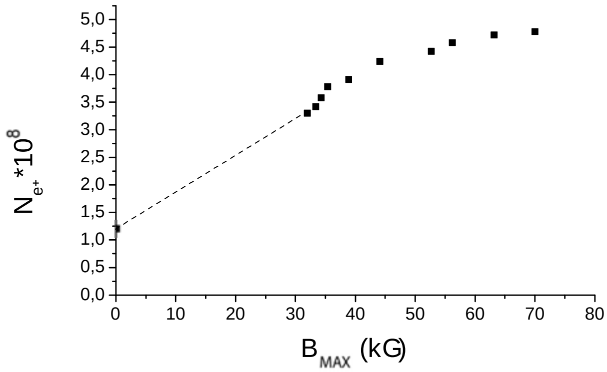

Figure 5: The dependence of positrons number upon the maximum field in matching device. Driving electron beam energy — 265 MeV, number of electrons in the primary electron beam — $1.8{\cdot}10^{10}$.

magnetic field on the geometrical axies of matching device. In ideal case the transverse component of magnetic field should be absent on the axis. The reality is different. Minimization of transverse component on the axies is a key point of this pulsed magnet design. Transverse magnetic field on the positron beam trajectory leads to transverse kick of positron beam and as a result to additional losses of positrons in the first accelerating structure. Nonzero transverse component of magnetic field on the axis in principal connected with nonuniformity of longitudinal field (this nonuniformity is necessary for normal operation of the device) and presence of insulating gap (which is used to form proper current distribution). For ideal axially symmetrical magnetic field of matching device the dependence of captured positrons number upon the field strength should increase monotonously up to 10 Tesla of maximum magnetic field (in the case of VEPP-5 positron source). The presence of maximum in this dependence indicates the appearance of unacceptable transverse kick of positron beam in matching device. Fig. 5 shows the corresponding dependence for VEPP-5 positron source (the result of experiment). The dependence is monotonous. It demonstrates a good enough quality of matching device operation.

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