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STATUS OF VEPP-5 INJECTION COMPLEX

F. Emanov*, K. Astrelina, A. Andrianov, V. Balakin, A. Barnyakov, O. Belikov, D. Berkaev, Yu. Boymelshteyn, D. Bolkhovityanov, A. Butakov, S. Vasilev, V. Yudin, G. Karpov, A. Kasaev, A. Kondakov, N. Kot, G. Kurkin, R. Lapik, N. Lebedev, A. Levichev, Yu. Maltseva, P. Martyshkin, S. Motygin, A. Murasev, V. Myslivets, D.Nikiforov, A. Pilan, S. Samoylov, Yu. Rogovsky, A. Tribendis, A. Frolov, A. Pavlenko, A. Batrakov, E. S. Kotov
The Budker institute of nuclear physics, Novosibirsk, Russia

Abstract

VEPP-5 injection complex is being put into operation as beam source of VEPP-2000 and VEPP-4 colliders at the end of 2016. Since then injection complex demonstrated maximum positron storage rate $1.7 \cdot 10^{10} s^{-1}$ and stable operation at the energy of 430 MeV. Latest operation results and prospects are presented.

INTRODUCTION

VEPP-5 injection complex (IC) is linear accelerator based electron and positron beam source with damping ring (DR) intended to supply BINP colliders VEPP-4 [1] and VEPP-2000 [2]. Layout of injection complex with colliders is shown in Fig. 1. It comprises of electron and positron S-band linear accelerators with achieved energies 280 MeV and 430 MeV, damping ring and a set of beam transfer lines named K-500. Originally, injection complex was planned to feed phi-factory and charm-tau factory so its design energy is 510 MeV. In order to supply charm-tau factory it is required to increase beam energy after damping ring with linear accelerator why short enough bunches from damping ring were required. In order to form bunches with σ_s about 1 cm 64th revolution harmonic 700 MHz RF cavity was used in damping ring. Since current beam users can accept much longer bunch in 2017 RF cavity was replaced by 1st revolution harmonic 10.94 MHz one. New cavity also can accept longer beam from linac what gives possibility to increase storage rate. Key parameters of injection are shown in Table 1.

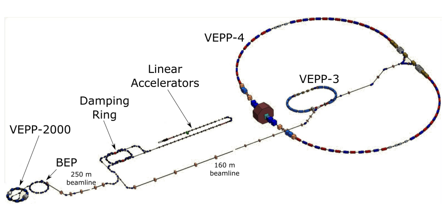

Figure 1: Injection complex and colliders layout.

Electron beam after first linear accelerator can hit tantalum target in order to produce positrons or bypass target and further accelerate electrons. In that case electron and positron beams can have different energies. VEPP-2000 in some cases requires time to switch between electrons and positrons to be less than 1 minute. To meet this requirement we keep damping ring mode the same or very close for electrons and positrons while linacs are tuned to match beam energy and switch particles. This allows to switch particles and start storage in 6 seconds for injection complex while K-500 requires at least 30 seconds to change main magnets polarity due to power supply power limitations. Beam storage/transfer, particles and users switching was automated with simple asynchronous state machine which uses 4 pretuned modes for the same beam energy (one for each beam user and particles kind). We use 12 transitions between K-500 modes in order to remagnetize its elements predictably. Currently injection complex can feed VEPP-2000 automatically but operator attention is required to switch to VEPP-4. More detailed description of operation techniques can be found in paper [3].

Table 1: Injection Complex Parameters

Parameter	**Value**
Linac energy	280, 430 MeV
Linac RF frequency	2855.5 MHz
Damping ring max.energy	510 MeV
Damping ring perimeter	27.4 M
Damping ring RF frequency	11.94 MHz
Max. e+ storage rate	$2.7 \cdot 10^{10}$
Damping ring design current	30 mA
Linac beam energy spread e+, e-	3%, 1%
repetition rate	12.5 Hz
Damping times at 510 MeV, h/v/l	11/18/12 ms
Design horizontal emittance	$2.3 \cdot 10^{-6}$ rad · cm
Design vertical emittance	$0.5 \cdot 10^{-6}$ rad · cm

OPERATION RESULTS SINCE 2019

Currently injection complex is routinely proving beams for BINP colliders. Previously operation results were reported in paper [4]. Season 2019/2020 was started with new cathode assembly giving $3.3 \cdot 10^{11}$ electrons per gun pulse. In January 2020 cathode heater current was reduced in order to give better cathode lifetime. This reduced gun electrons number per pulse to $2.2 \cdot 10^{11}$. Then in summer 2020 we replaced gun grid modulator with quite shorter pulse one and now gun gives about $1.5 \cdot 10^{11}$ electrons per pulse. In October 2019 positron solenoid was damaged resulting in single injection e+ number reduction to $0.85 \cdot 10^{9}$. Seasons

* f.a.emanov@inp.nsk.su

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2019/2020 and 2020/2021 operation values are presented in Table 2.

Operation Energy Increase

In 2016 injection complex stably reached beam energy of 390 MeV which was limited by positron linac energy. Energy increase can lead to better injection efficiency in damping ring and also can make VEPP-3 operation easier. In the beginning of season 2020/2021 more accurate linac tuning was performed and 430 MeV beam energy was stably reached. Now we preparing to conduct accurate RF power measurements in order to determine if beam energy limited by available RF power. If there are enough power waveguide modifications will be required in order to increase beam energy.

Table 2: Operation Parameters Since September 2019

Parameter	**2019/2020**	**2020/2021**
Beam energy, MeV	390	430
Maintenance/operation, hr	341/3528	
Max. e+ storage rate, e+/s	$2.1 \cdot 10^{10}$	$0.7 \cdot 10^{10}$
Max.Single injection, e+	$1.7 \cdot 10^{9}$	$0.7 \cdot 10^{9}$
Max.Single injection, e-	$1.4 \cdot 10^{10}$	$1.2 \cdot 10^{10}$
Transfer efficiency, %	Up to 60	Up to 50
injection repetition rate, Hz	12.5	10

ACTIVITIES

Reliability

In season 2019/2020 injection complex reliability is about 90%. Most of the downtime and most failure cases was caused by linac klystron modulators which contains outdated electronics. Also big number of failures were observed for magnetic system power supplies. Old magnetic system power supplies already partly replaced and it is planned to gradually replace outdated electronics. Also we managed to reduce recovery time after power outages or similar events.

Beam Loss Monitor

Optic-fiber beam loss monitor was developed and deployed to initial part of K-500 [5] as shown on Fig. 2. Recently device was fully integrated in injection complex control system and now routinely used in k-500 tuning.

Control System

Injection complex software based on CXv4 framework [6]. Control software set constantly improved and some previous states are described in papers [7, 8]. There are listed recent changes:

- Many base framework improvements was implemented.
- Server-side device/channel bridging, used to easily interface beam user control systems.
- EPICS and TANGO client modules for CX.
- Improved python bindings for CX client libraries.

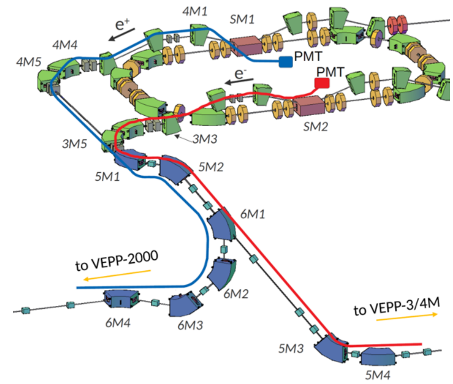

Figure 2: Beam loss monitor layout.

- Improved CX-connected Qt widgets set.
- Improved Database tools for machine configuration, configuration files generation.
- Improved machine state snapshot storage and manipulation programs.
- Improved automatic and data preprocessing software.
- Developed a software set for damping ring optic measurement and studies.
- Developed few data preprocessing services and operators frontend applications.

Recently was setup common network of injection complex and VEPP-4 as was proposed earlier [9]. This network used to share K-500 diagnostics data and accelerators statuses between control systems. Communication between injection complex and VEPP-2000 yet involves BINP network and VPN.

Beam Diagnostics for Injection Channels

Beamlines from linac to damping ring don't have any non-destructive diagnostic devices. We think a set of beam position monitors can allow us to tune injection lines more accurately and reduce operation efforts to stabilize injection from linac. Layout of proposed beam position monitors placing shown on Fig. 3. See dedicated report for details of channel diagnostics consideration [10].

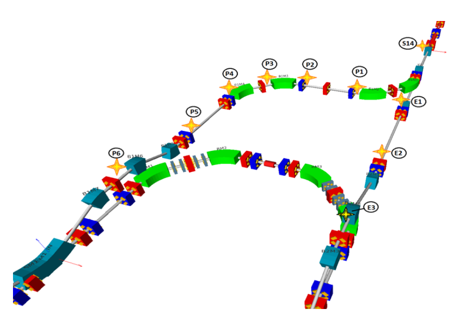

Figure 3: Proposed beam position monitors placing.

Linac RF System Monitoring

Few CAMAC 200 MHz digitizers and channel switchers had been used for linac RF system before 2019. This system was not able: to observe all signals at the same time, to work

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with common clock source and last years was completely unsupported. In 2019 system was replaced by 10 ADC250x4-4ch assembled in one VME64 crate with L-timer, used equipment described in following papers [11, 12]. L-timer was adapted to operate with injection complex master generator and synchronization system as clock and start signals and take simultaneous snapshot from all ADCs. System fully integrated into injection complex control environment but more automatic data preprocessing is under consideration now. Measurement points layout of RF signal shown on Fig. 4.

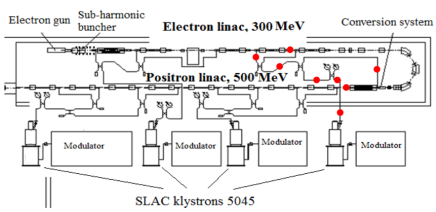

Figure 4: Linac RF measurement points layout.

Positron Solenoid

Since positron solenoid was damaged in 2019 e+ storage rate was reduced by more then two times. It is only possible to replace whole unit so we now designing new solenoid with better field quality due to the absence of gaps between coils. Magnetic field and impact to beams are now estimated. See expected magnetic field on Fig. 5. Mechanical design and beginning of new unit production planned to 2021/2022 season.

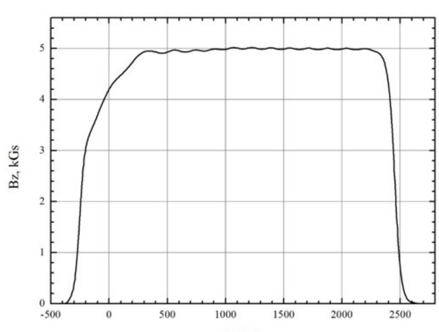

Figure 5: Expected new positron solenoid magnetic field.

CONCLUSION

The VEPP-5 injector successfully performs its task of delivering electron and positron beams to BINP colliders. A record-high rate of positron injection into the damping ring ($1.7 \cdot 10^{10}$ p/s) was reached in 2019.

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