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CONSIDERATION THE PROSPECTS OF BEAM DIAGNOSTIC SYSTEM UPGRADE IN THE TRANSPORT CHANNELS OF INJECTION COMPLEX VEPP-5

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Abstract

Transport electron and positron channels from linear accelerator to storage ring of Injection Complex VEPP-5 (BINP, Novosibirsk) have a complicated 3D configuration and are equipped only with luminophore screens as a beam test. For the regular machine operations the non-destructive beam diagnostic system is required to adjust the electron and positron beam trajectories and minimize the beam losses. The proposal of new beam position monitors (BPM) assembling is considered. Newly added BPMs allow one to control the beam trajectory during operations. Collecting beam position data in several points makes it possible to calculate and correct the beamline parameters: Twiss parameters, dispersion, beam energy variations. The possible configuration of the new BPMs placing is suggested and the rate of beam loss reducing due the additional diagnostics is estimated.

INTRODUCTION

Injection Complex VEPP-5 operates in BINP since 2016 and is used to provide intense electron and positron beams to the two operating colliders VEPP-4M and VEPP-2000 [1]. The complex (IC) consists of the chain of two linear accelerators and conversion target (Preinjector or Linac), circular Damping storage ring (DR) and transport channels. Two separate channels (see Fig. 1) are used to inject electrons and positrons to DR. Beam parameters after acceleration in Preinjector are presented in Table 1.

Both injection channels have vertical chicanes to inject beams into straight lines of DR. Positron injection channel also contains the horizontal achromatic beam translation.

Table 1: Beam Parameters Before the Injection

Parameter	e+	e-
Energy	430	430
Number of particles	$2 \cdot 10^{10}$	$2 \cdot 10^{9}$
Energy spread	2%	15%

The existing system of diagnostics in the injection channels includes six luminophore screens for positron line and three for electron line. It occurs to be not sufficient to adjust the trajectory and minimize beam losses during the regular operations. The idea to assemble the non-destructive diagnostics system based on electrostatic beam position monitors (BPM) was proposed. Its main advantage is in ability to obtain data fastly in several points simultaneously so the system can be used during regular machine operations.

CALCULATION OF BEAM PARAMETERS USING BPM DATA

Beam transverse coordinates at two BPMs (which can be designated as BPM0 and BPM1) are related with the transport matrix. It depends on magnet fields and distance between BPMs. For the motion in straight channel the coordinates and angles of the beam center can be represented as:

$$\begin{cases} x_1 = M_{11}x_0 + M_{12}x_0' \\ x_1' = M_{21}x_0 + M_{22}x_0' \end{cases}$$

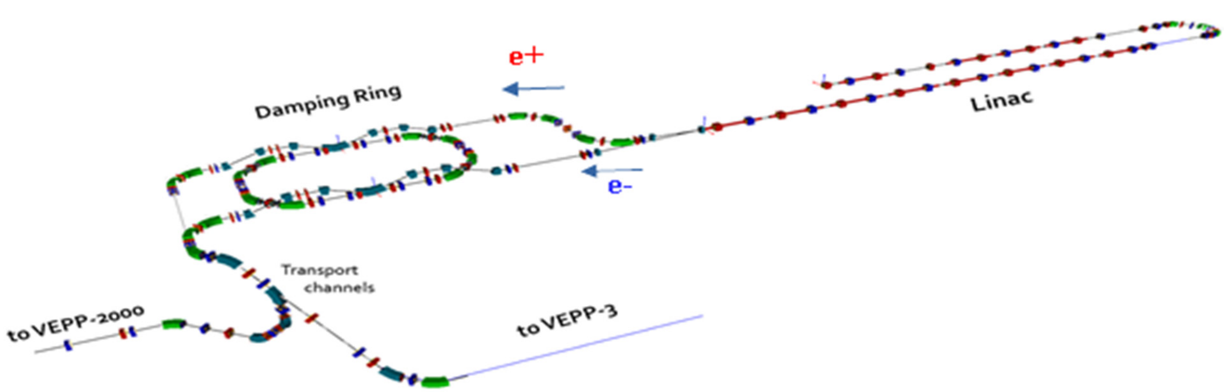

Figure 1: The layout of Injection Complex VEPP-5, its components and initial sections of the transport channels to colliders VEPP-4M and VEPP-2000.

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where M_{ij} are the elements of 2x2 transport matrix [2]:

$$M_{11} = \sqrt{\frac{\beta_1}{\beta_0}}(cos\psi + \alpha_0 sin\psi)$$

$$M_{12} = \sqrt{\beta_0\beta_1} sin\psi$$

$$M_{21} = \frac{(1+\alpha_1\alpha_0)sin\psi + (\alpha_1 - \alpha_0)cos\psi}{\sqrt{\beta_0\beta_1}}$$

$$M_{22} = \sqrt{\frac{\beta_0}{\beta_1}}(cos\psi - \alpha_1 sin\psi)$$

β, α and are Twiss parameters at BPMs' positions, ψ – phase advance between them, x and x' - transverse beam coordinates at BPM0 and BPM1. Same expressions are used for the y plane.

Elements of matrix M can be calculated using lattice data (i.e. magnet field maps, distances precision measurements etc.). Twiss parameters at two monitors are related with Steffen matrix (see Eq. (6) in [2]). Thus there are 6 equations (5 of them are independent) with values x_0', x_1', ψ, β_0 and α_0 left unknown. Thus for two BPMs data there are 5 variables and 5 equations. That should be enough to calculate all of the unknowns numerically with model parameters as the initial guess. Adding one or more BPMs or variating channel optics and trajectory with controlled shifts would increase the accuracy of calculations but 2 BPMs is the minimum number of monitors required.

Dispersion

At the non-straight parts of transport channels (achromatic bends, chicanes) the dispersion functions should also be taken into account:

$$\begin{cases} x_1 = M_{11}x_0 + M_{12}x_0' + \eta_0\delta_p \\ x_1' = M_{21}x_0 + M_{22}x_0' + \eta_0'\delta_p \end{cases}$$

η and η' are the dispersion and its derivative, δ_p – energy spread. Unknown variables here are: x_0', x_1', ψ, β_0 α_0, η_0, η_0' and δ_p. To find all of them we need not less than 3 BPMs (or two series of measurements with variated channel optics).

PLACING THE MONITORS IN THE CHANNELS

A set of new BPMs (the length of single monitor is 10 cm) and their electronics can possibly be produced for injection channels. Their main characteristics can be found in [3].

According to the standard recommendations [2] the most informative is to place 3-4 monitors per one period of betatron oscillations. That corresponds to 6-7 monitors for the positron channel and 4-5 for the electron. Moreover, there should be enough space between magnets and other equipment. Some electrostatic BPMs may replace the existing luminophore screens.

A version of BPM placing in the channels is shown at Fig. 2. Possible locations of monitor installation are indicated with yellow stars. There are pairs P1-P2, P4-P5 and E1-E2 which are placed in the gaps with zero dispersion at one plane. They can be used to control horizontal dispersion η_x after achromats for positrons, vertical η_y for electrons - and to calculate Twiss parameters. Three monitors P2, P6 and E3 are to measure and control non-zero dispersion within bends and chicanes [4].

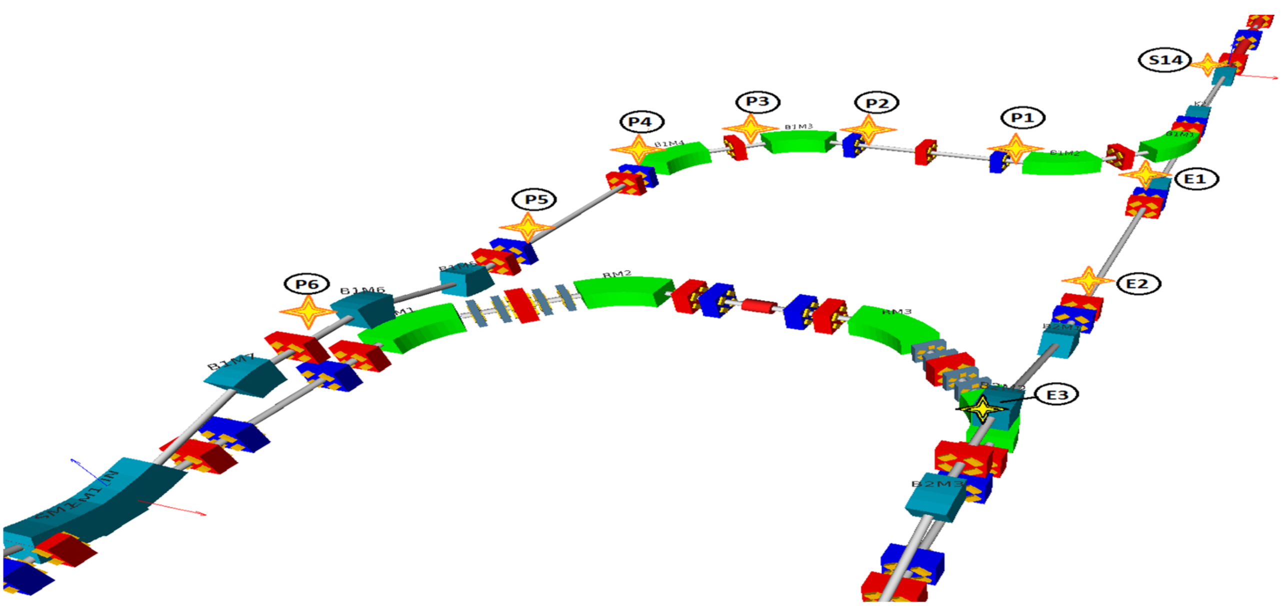

Figure 2: Possible placement of the monitors. The locations which are suitable to place the new BPMs indicated with yellow stars. Letter 'P' assigned for the positron injection channel, letter 'E' - for electron injection channel. Monitor named 'S14' is located at the last accelerating section of Preinjector.

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BEAM LOSS REDUCING

There is amount of particles that will be lost anyway (transport channels and Damping ring have less energy acceptance than Preinjector). Nevertheless the new diagnostic set should prevent additional losses related with trajectory or optics inaccuracies.

The results of numerical simulations of average beam loss rate are presented at the Figs. 3 and 4. Quadrupole lens gradient random errors are set in range of 5%, energy deviation – 1%, beam orbit shift – less than 5 mm. Simulations were performed using multiparticle tracking with 'elegant' code [5].

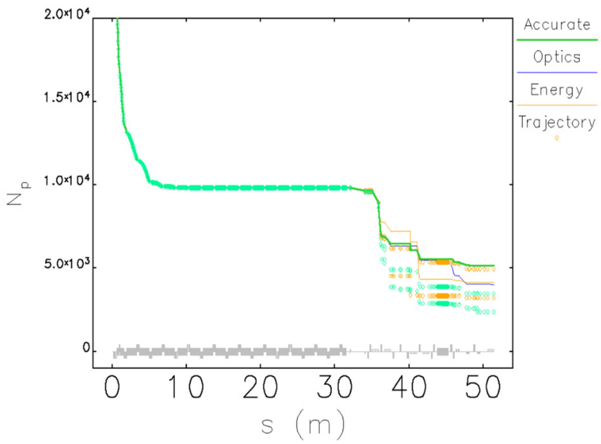

Figure 3: Beam losses in the positron injection channel. Thick green line is for the best optimized beam transportation with no errors.

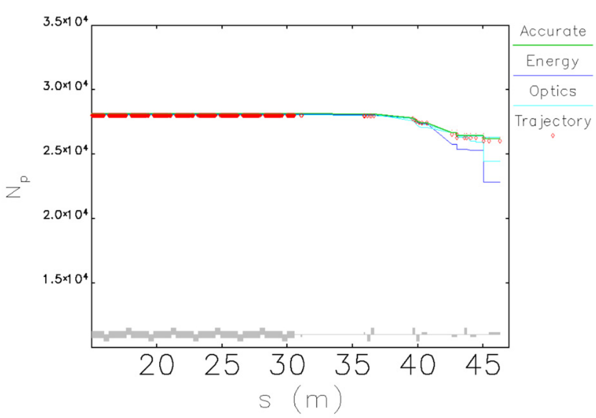

Figure 4: Beam losses in the electron injection channel.

Adding the random errors to the channel models results in additional particle losses: 30-55% for positron transportation. Electron channel is not so sensitive to the orbit inaccuracy but 1-5% of particles also can be lost.

CONCLUSION

The project of beam position monitor placement is proposed. The concept suggests to use six electrostatic non-destructive diagnostic sets for positron channel and three for electrons. The possibility to calculate the beam optics functions (Twiss parameters), energy deviations, correct beam angles and positions has been analysed.

More accurate beam positioning would result in avoiding the significant part of excessive particle loss for positron transportation and 5% for electrons.

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