Consideration the Prospects of Beam Diagnostic System Upgrade in the Transport Channels of Injection Complex VEPP-5

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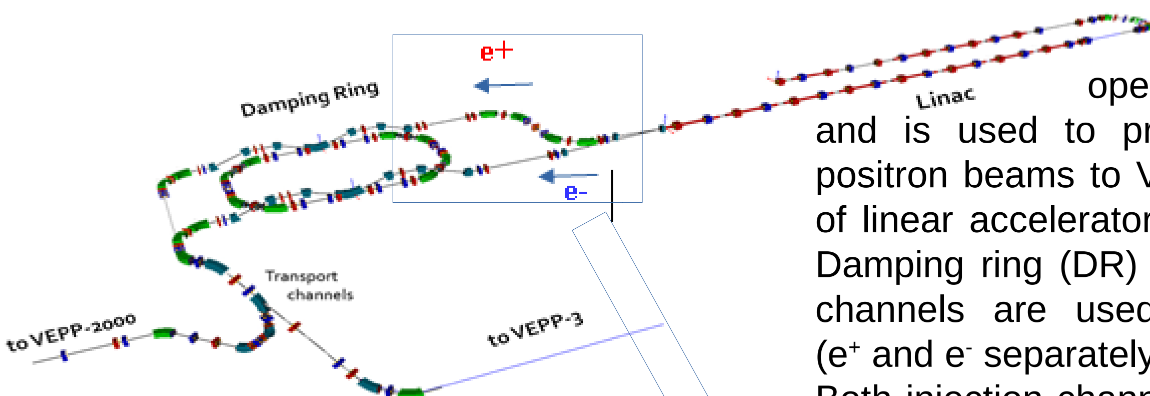
Abstract

- 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 increase of injection efficiency due the additional diagnostics is estimated.

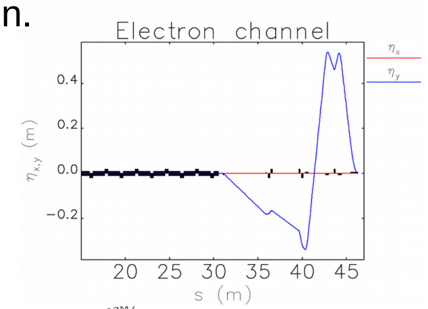


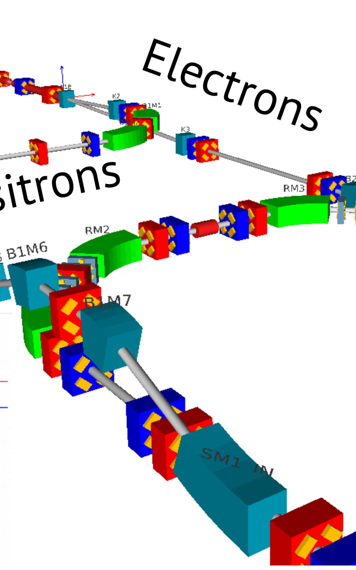
Injection Complex VEPP-5 operates in BINP since 2016 and is used to provide intense electron and positron beams to VEPP colliders [1]. It consists of linear accelerators (Preinjector/Linac), circular Damping ring (DR) and transport channels. Two channels are used to inject particles to DR (e^+ and e^- separately).

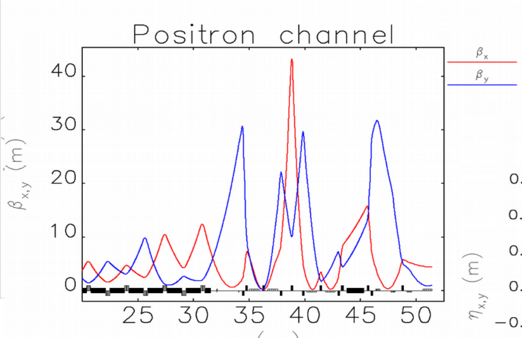
Both injection channels have vertical chicanes to inject beams into straight lines of DR. Positron injection channel also contains the horizontal achromatic beam translation.

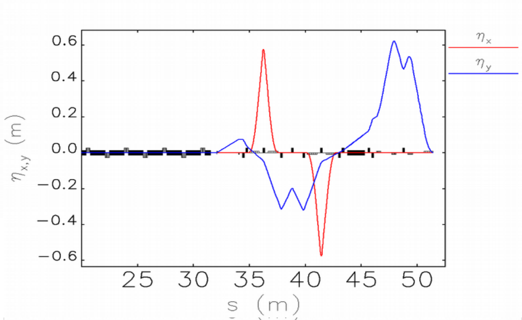
Beam parameters after acceleration in Preinjector :

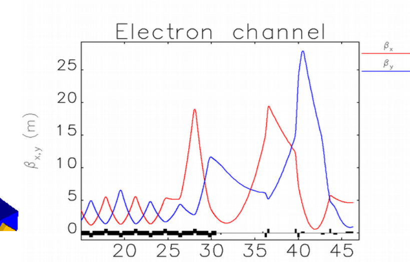
	e^-	e^+
Energy	430 MeV	
Number of particles	$2 \cdot 10^{10}$	$2 \cdot 10^{9}$
Energy spread	2%	15%











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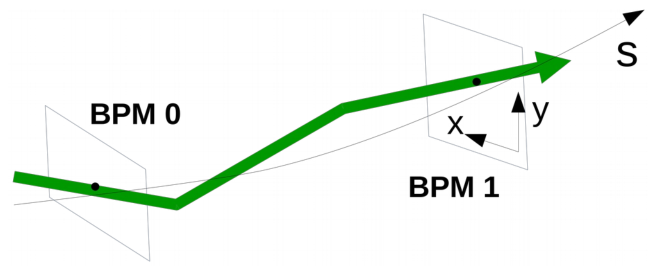
Calculation of beam parameters using BPM data



- Beam transverse coordinates on two BPMs are related with transport matrix. It depends on magnet fields and distance between BPMs "0" and "1".
- *If energy stable* [3]:

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

where

$$M_{11} = \sqrt{\frac{\beta_1}{\beta_0}}\left(\cos\psi + \alpha_0 \sin\psi\right) \qquad M_{12} = \sqrt{\beta_0 \beta_1}\sin\psi$$

$$M_{21} = \frac{\left(1+\alpha_1 \alpha_0\right)\sin\psi + \left(\alpha_1 - \alpha_0\right)\cos\psi}{\sqrt{\beta_0 \beta_1}} \qquad M_{22} = \sqrt{\frac{\beta_0}{\beta_1}}\left(\cos\psi - \alpha_1 \sin\psi\right)$$

β, α and ψ are Twiss parameters at BPMs' positions, x and x' - transverse beam coordinates at BPM 0 and BPM 1. Same expressions used for y plane.

- What can we do with it?

- Collect data from a number of repetitive beam shots. Beam trajectory is mostly stable. (If not, the shot can be ignored)
- Calculate elements of matrix *M* using lattice data
- Variate channel optics and trajectory
- Unknown parameters are: x', ψ, β_0 and α_0

2 BPMs – minimal number of monitors to find all unknowns (5 variables for 5 independent equations)

- *If energy changes:*
- When Preinjector operates, the energy of transported beams can be shifted. Dispersion functions should be included:

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

η is dispersion, δ_p – energy spread.

Unknown parameters here are: x', 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)

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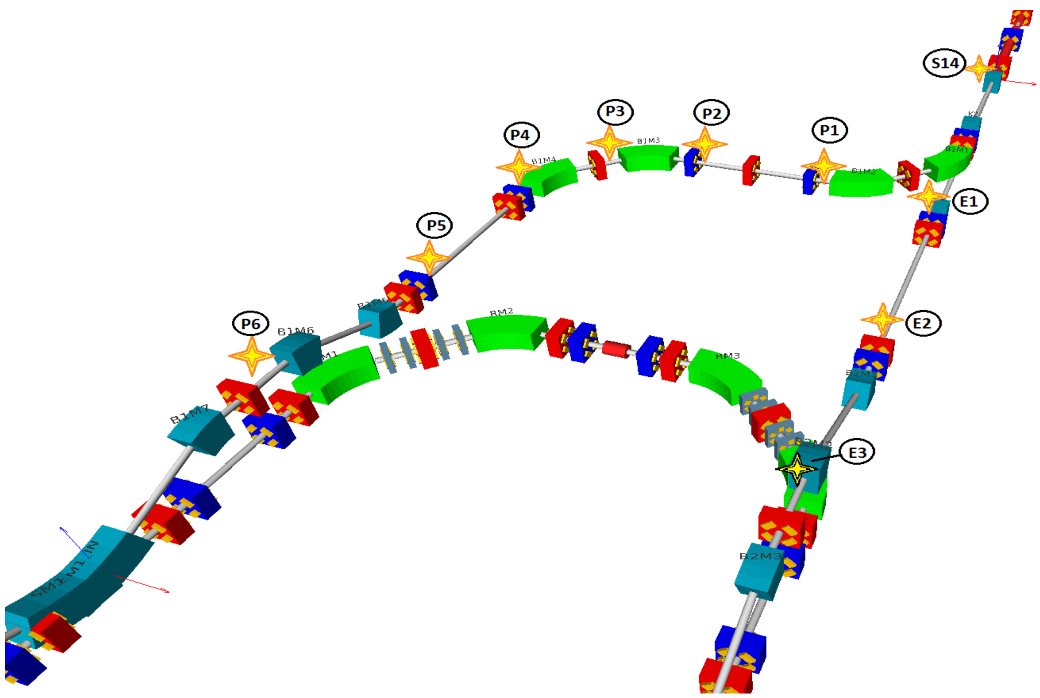
Where to assemble new monitors? (the sketch of placement)



A set of new BPMs (length 10 cm) and their electronics can be produced in BINP (same as in [2])

Positrons:

P1-P2 and P4-P5 pairs – to set in straight drifts; can be used to control horizontal dispersion η_x after achromats;

P3 – for η_x where it is not zero;

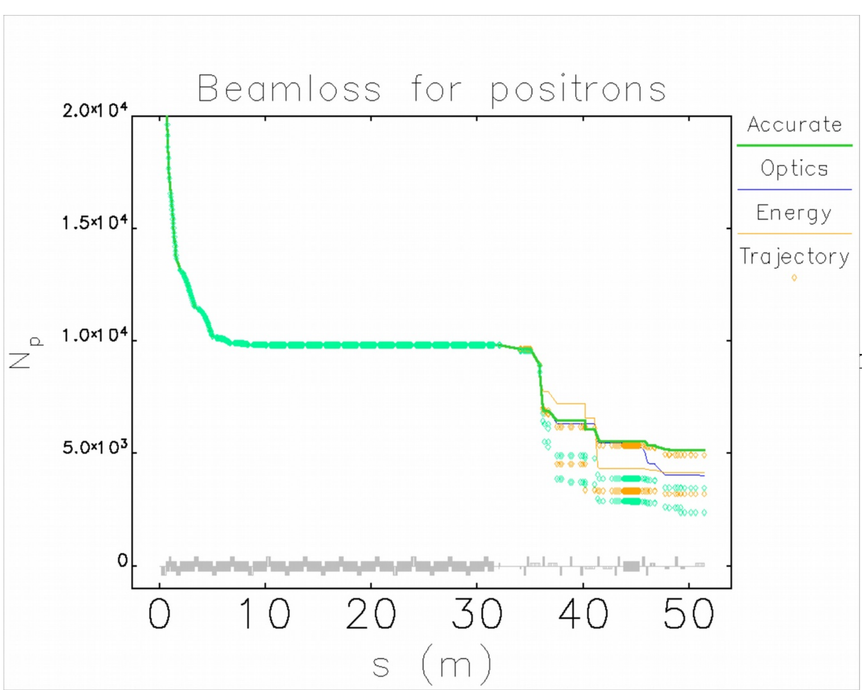
P6 – same for vertical dispersion η_y

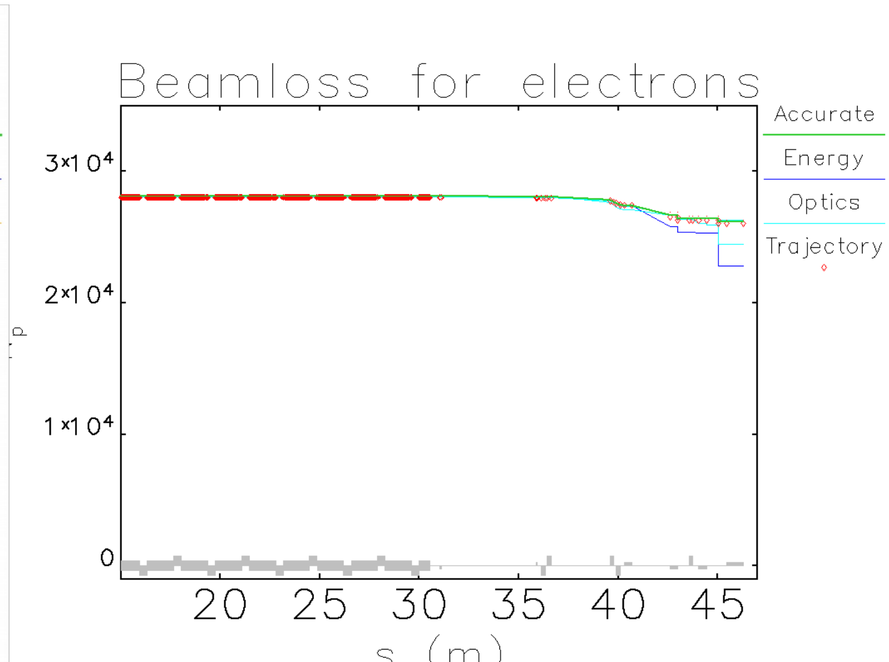
Electrons: 3 BPMs (E1, E2,E3) for Twiss parameters and for vertical dispersion η_y measurements and control

There should be enough space between magnets and other equipment.

How can it help?

There is amount of particles that will be lost anyway (transport channels have less energy acceptance than linear accelerator). Nevertheless the new diagnostic set should prevent additional losses related to trajectory or optics inaccuracies. The results of numerical simulations of average beam loss rate are presented below. 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 [4]





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Conclusions

- The project of BPM placement is proposed; 6 sensors for positron channel and 3 for electron;
- More accurate beam positioning would result in avoiding 30-55% excessive particle loss for positron transportation and 1-5% for electrons;
- New data analysis can be used to calculate beam optics functions, energy deviations, correct beam angles and position in the entrance to injection channels.

References

[1] VEPP-5 Injection complex performance improvement for two collider operation. 26th Russian Particle Accelerator Conference, https://doi.org/10.18429/JACoW-RUPAC2018-TUZMH02

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[5] Arduini, G. and Giovannozzi, M. and Hanke, K. and Manglunki, D. and Martini, M. "New methods to derive the optical and beam parameters in transport channels", Nucl. Instrum.