ISBN: 978-3-95450-240-0 ISSN: 2673-5539 doi:10.18429/JACoW-RuPAC2021-WEPSC56

BEAM PARAMETERS MEASUREMENT AND CONTROL SOFTWARE TOOLS FOR VEPP-5 INJECTION COMPLEX DAMPING RING

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Abstract

Beam parameters control and operation software tools for BINP VEPP-5 injection complex damping ring consisting of two parts were developed. Beam parameters control includes processing of measured turn-by-turn beam coordinates from all damping ring beam position monitors and displaying such features as tunes and beam position into vacuum chamber. This part gives an opportunity to measure damping ring response matrices and carry out its processing too. Beam parameters operation is based on knobs creating. Knob is combination of accelerator control elements, which performs an isolated shift of one selected parameter, e.g. only vertical betatron tune. This part is devoted to their creation and application on VEPP-5 injection complex. This paper presents review of developed software tools and their application result on VEPP-5 injection complex: beam position adjustment via response matrix measurements and quantification the amount of damping ring captured particles during the injection process depending on beam tunes.

VEPP-5 INJECTION COMPLEX

Injection complex VEPP-5 (IC) is a part of VEPP-4 - VEPP-2000 electron-positron colliders complex. It intended for high-energy, nuclear physics and synchrotron radiation experiments conducting. IC (Fig. 1) constists of electron gun, 2 linear accelerators, $e^- \to e^+$ conversion system, damping ring and transport channels K-500 [1].

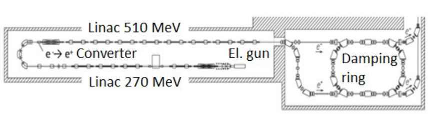

Figure 1: VEPP-5 injection complex scheme.

SOFTWARE TOOLS DESCRIPTION

Beam position monitors (BPM) data processing is a key weapon for obtaining information about beam parameters and their response on accelerator magnetic system changes. Software tools, which includes data obtaining, processing, displaying and keeping, was developed to take advantage of the BPM potential. Software tools are consist from 3 parts:

- Daemons:
  - BPM data processing - *orbitd*
  - knobs service - *knobd*
- GUI-applications for operational staff:
  - damping ring beam positions displaying and keeping in different IC modes - *orbit*
  - turn-by-turn measurements displaying - *turns*
  - tunes displaying and keeping - *tunes*
- GUI-applications for administration:
  - damping ring response matrix collecting - *rmc*
  - magnetization of magnetic system elements - *magn*
  - user application for knob creating and using - *knob*
  - measurement of injected particles number into damping ring vs. tunes - *inj_resp*
  - collected response matrix processing and based on them knob creating - *rmc_proc*

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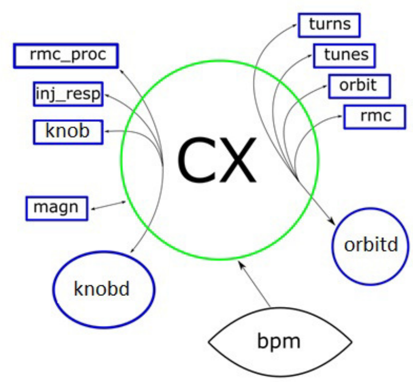

Figure 2: Software tools principal scheme.

Software tools principal scheme is presented on Fig. 2. Black arrows show links between different parts of software, which communicate each other throw CX-server [2].

Program separation into daemons and GUI-applications are conditioned by the need to separate direct processing of data from the display and use of the results of this processing. On the one hand, this gives an opportunity to independly change each component (logic or visualization) without affecting another part, from other hand, running multiple copies of displaying application requred only one copy of daemon with data processing.

SOFTWARE TOOLS USAGE ON INJECTION COMPLEX

Lattice

Damping ring has 28 quadropole lenses, which means that detecting the tunes shift from varying the current of qudrupole corrector of each lens allows us to measure aver-

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aged beta-function in the lens location [3]. A small change of lens gradient leads to betatron tune shift according to formula $\delta\nu = \frac{1}{4\pi}\int \delta k * \beta(s)ds$. Averaging the beta-function over lens lenght we can get sought value: $<\beta>\approx \frac{4\pi}{L}\frac{\delta\nu}{\delta k}$. Conducting the measure of betatron tunes shift vs. lens gradient becomes possible calculate value of $\frac{\delta\nu}{\delta k}$ via $\nu(k)$ approximation and $<\beta>$ too. Results of such type measurements is shown on Fig. 3.

Analysing the data it becomes clear that the theoretical model prediction (green line on Fig. 3) and beam behavior (blue points) in accelerator based on measurements are different. Now, theoretical model of damping ring is under calibration process.

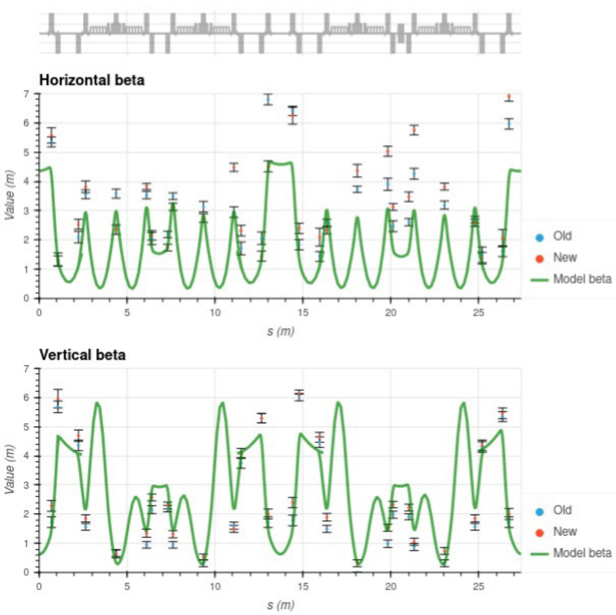

Figure 3: Measured (red points - after beam position correction, blue - before) and model beta-functions.

Responce Matrix

Responce matrix is a table of correspondance between variation of magnetic system element current and change of beam position inside accelerator vacuum chamber [3]. Algorithm of response matrix measurements is the following:

- Magnetizing the elements of the magnetic system of the accelerator to be in the same branch of the iron hysteresis each time. This ensures repeatability of the measurement procedure and further application of the response matrix.
- Selection of the elements necessary for the measurement of the matrix and setting the parameters for the measurement of the matrix. Depending on the objectives of the experiment, these can be quadrupole and dipole correctors or other elements of the magnetic system.
- Conducting a series of beam position measurements depending on choosed elements current. It worth noting the fact, that it is necessary to track power supply status. If it gives adjusted current the algorithm goes further or mark the correctos as unactive otherwise, removing it from response matrix measurement process.
- Based on measurements, formation the sought matrix, matrix with errors of each element calculation of response matrix and information about initial values of magnetic system elements.

Given response matrix can be used for theorethical accelerator model calibration. Calibration is the process of varying theoretical model parameters to achieve equality (with given precision) of the response matrix and theoretical response matrix (calculated the same way, but on the accelerator model).

Another application of the response matrix is to conduct beam position correction. Using SVD with measured response matrix we can get pseudoinverse matrix and calculate the current shift of magnetic elements, which were used in response matrix measurements, to create preassign beam position shift (actually, this operation will create the knob). Figure 4 demonstates the result of above procedure accomplished on injection complex damping ring. The aim of this correction was to minimize horizontal beam coordinates along damping ring perimeter. Blue markers showed beam position before correction using created knob, green - after. Corresponded values of beta-function before and after correction is presented on Fig. 3.

Figure 4: Displaying damping ring beam position. Green marker is the last measured beam coordinate, blue marker is the saved position, red is the inactive BPM's.

Number of Injected Particles vs. Tunes

Beforehand calculated knob for tunes shifting can be use for measuring the amount of captured particles onto damping ring during injection process depending on betatron tunes. For this is nessesary to point tunes in requared position and to make several beam shots from linac to damping ring in order to fix amount of captured beam particles. Next step is to moves tunes to another point by knob and to repeat shot

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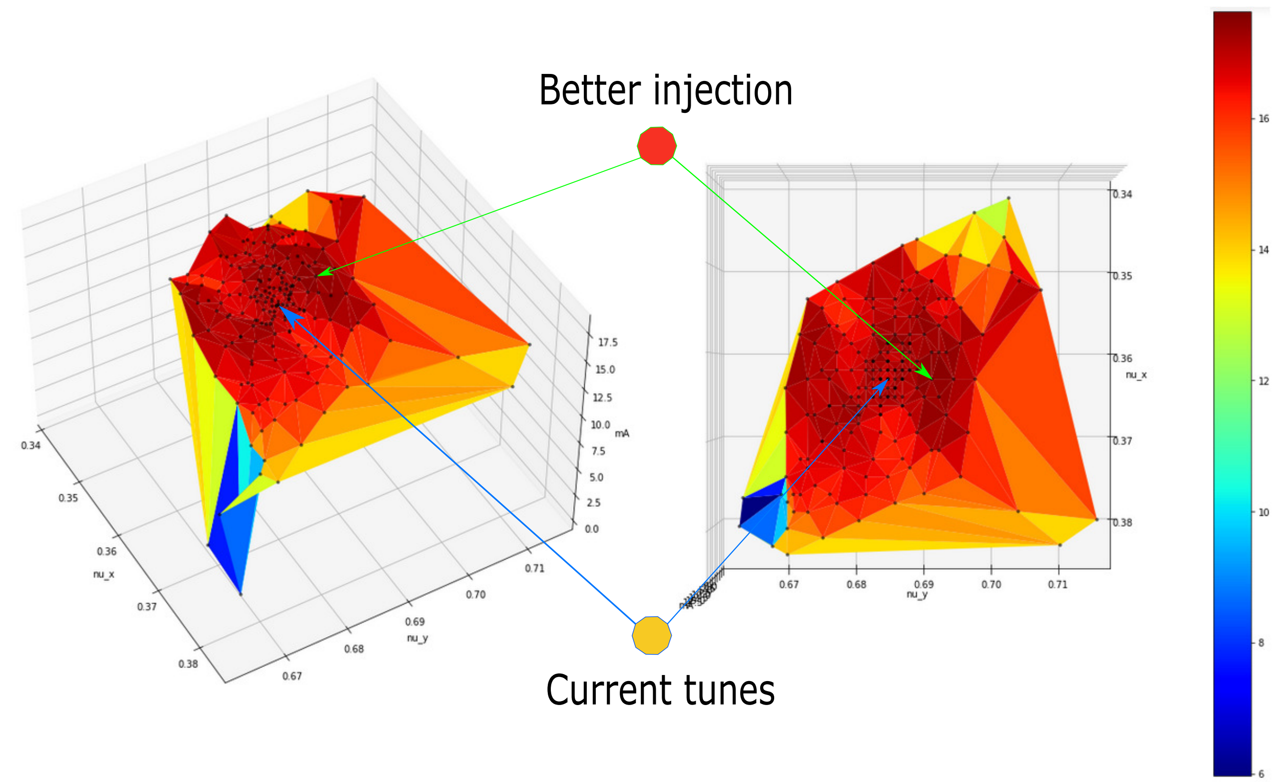

Figure 5: Amount of damping ring captured particles vs. tunes for "VEPP-2000 positron" IC mode.

and fix procedure. As a result of this algorithm usage we will receive desired distribution.

Program *inj_proc* implements the described algorithm and gives an opportunity to choose one or two knobs for tunes scanning, mesh parameters and shots amount for averaging. Thus, user gets one or two dimensional distribution of captured particles during injection process vs. tunes. Output data has Python-like dictionary format.

Fig. 5 shows plotted distribution for "VEPP-2000 positron" IC mode. It is clearly seen that in the immediate vicinity of the current betatron tunes there is another point, where more particles are captured (moreover, in this new point the amplitude of the betatron beam oscillation beats decrease).

Measurements were made by beforehand calculated knob, which means that we can correct tunes of damping ring with them and get an increase the amount of injected positrons.

CONCLUSION

Beam parameters control and operation software tools for VEPP-5 injection complex were developed. They cover a wide range of tasks: from BPM data processing to response matrix measurements and knobs creating. This software facilitates the injection complex setup process, which includes damping ring energy shifting, creating of local beam position distortion and tunes change.

Using created software were measured damping ring beta-functions, corrected beam position along damping ring perimeter and plotted dependence of damping ring captured particles vs. tunes.

Now such types of measurements and subsequent corrections of magnetic system and beam parameters can be routine procedure for injection complex operational staff.

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