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FAST KICKER FOR HIGH CURRENT BEAM MANIPULATION: EXPERIMENTAL FACILITY

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Abstract

The pulsed deflecting magnet (kicker) project was worked out in Budker Institute of Nuclear Physics. The kicker design parameters are: impulsive force, 1 mT*m; pulse edge, 5 ns; impulse duration, 200 ns. The unconventional approach is that the plates must be replaced by a set of cylinders. The obtained magnet construction enables the field homogeneity to be controlled by changing current magnitudes in cylinders. Furthermore, we demonstrated the method of field optimization. In addition, measurement technique for the harmonic components was considered and the possibility of control harmonic components value was demonstrated. The results with electron beam on actual facility was considered.

THE KICKER CONCEPT DESIGN

The kicker design should accept several requirements. The first one is vacuum chamber and kicker symmetry axis coincidences. The second one is that central angel should be about 90˚. The optimisation parameter is magnetic field homogeneity in centrally located square area (2 cm x 2 cm).

THE KICKER ACTUAL DESIGN

Taking into account the kicker design optimization results described in [1], the BINP designers developed a kicker prototype. The kicker dimensions were selected based on measurements. The magnet cross section is shown in Fig. 1. The physical magnet length is about 650 mm. The magnet aperture is 100 mm. The vacuum chamber diameter is 164 mm. The cylinder diameter is 28 mm. The cylinders are made of steel, as well as the body of the magnet. The ceramic feedthrough also was developed in BINP.

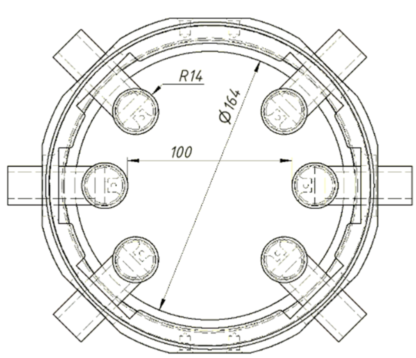

Figure 1: The kicker actual design (all dims are in mm)

MAGNETIC FIELD MEASUREMENTS

To control magnetic field quality the experimental measurements was carried out. Experimental stand and measurement technics was described in [2]. Simulated and measured field distributions being in good agreements.

Our design provide as with possibility to optimize field quality throw tuning current value in separate cylinders. One of the possible wire commutation shown in Fig. 2. In this type of commutation used just one pulse generator. Moreover, for provide proper current ratio in cylinders we need some Variable Resistance Unit.

Since the field distribution must be symmetric with respect to the horizontal plane we assume:

$$I_2 = I_6 = -I_3 = -I_5 = I_0,$$
$$I_1 = -I_4 = k \cdot I_0, \quad (1)$$

where k - some optimizing factor.

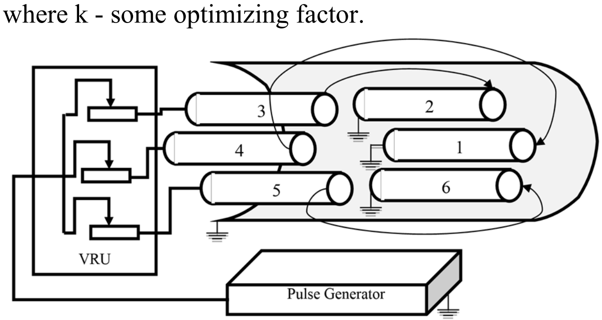

Figure 2: The kicker commutation diagram with Variable Resistance Unit (VRU).

The optimization goal is to minimize *ΔB* – field quality indicator:

$$\Delta B = \frac{B_{\max} - B_{\min}}{B_{\min}} \cdot 100\% \quad (3)$$

As a result of the optimization we have the following ratio: the first and fourth currents must be one point five times greater than others, i.e., k=1.5.

The results of optimization show good result in simulations. In Fig. 3 a) and 3 b) show magnetic field distribution with k=1 and k=1.5 respectively.

ELECTRON BEAM SIMULATIONS

For simulation beam dynamics was applied several approaches.

At the first was calculated electron beam emittance change with ASTRA [3].

They are next initial parameters: beam diameter 18 mm, kicker current was 120 A and 86 A for 5 MeV beam energy, and 359 A and 258 A for 20 MeV. Beam current 2000 A, length 2.5 ns, particles count 10^4.

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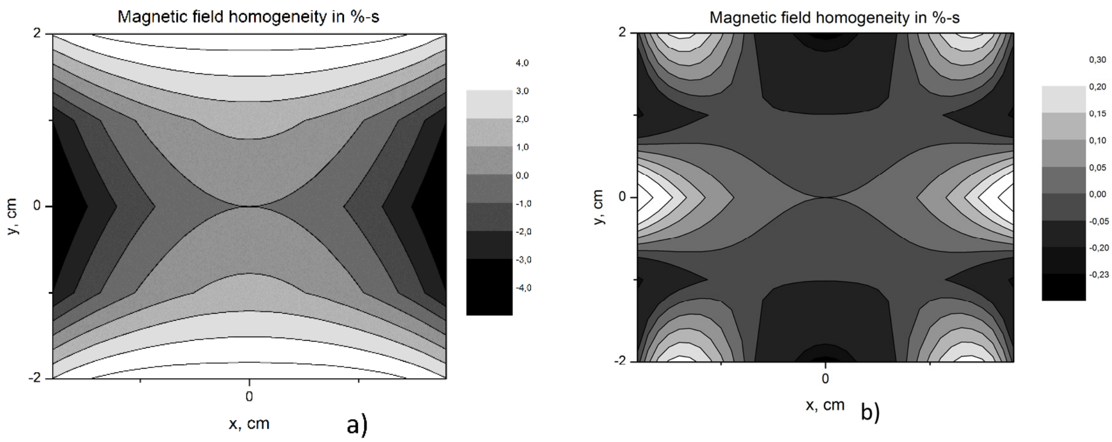

Figure 3: The kicker actual design (all dims are in mm).

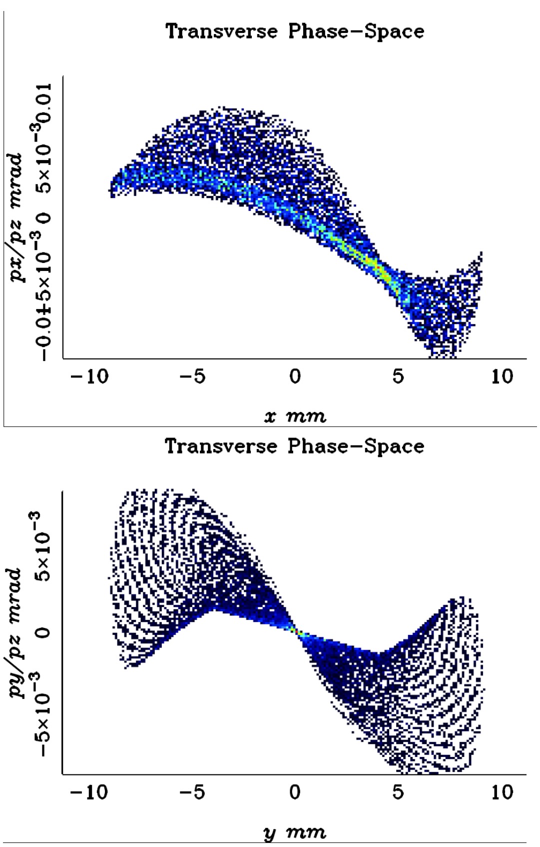

Figure 4: Beam phase-space for x (top) and y (bottom).

As output data, we obtain transvers Phase-Space after kicker (in Fig. 4. demonstrated Phase-Space for 20 MeV beam). Calculated emittances after kicker is ex=0.44 mm·mrad, ey=0.4 mm·mrad for 5 MeV, and ex=0.2 mm·mrad, ey=0.198 mm·mrad for 20 MeV. At the kicker start we assume that beam have zero emittance. (Calculations provided by Volkov Vladimir Nikolaevich, V.N.Volkov@inp.nsk.su).

Beam have big diameter – about 20 mm. For manipulate with this beam near septum was supposed to use horizontal beam compression using quadrupole. To optimize this parameters have performed optimization calculations in Elegant [4] (Astrelina Kseniya Vitalyevna, K.V.Astrelina@inp.nsk.su).

From optimization, we get next tracking parameters:

- Deflection angle in kicker: 0.52°
- Angle of entry into the septum-magnet: 1.1°
- Horizontal shift at the start septum-magnet: 46 mm.

Figure 5 shows the beam profile before septum-magnet.

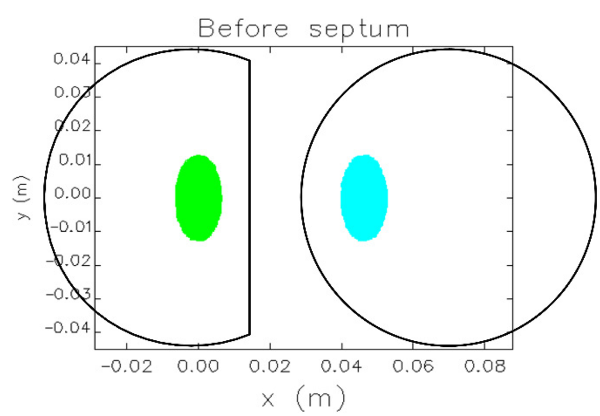

Figure 5: Beam before septum magnet. Direct channel – right.

In addition was carried out tracking simulations in CST Studio (with PIC- and TRK–solver) [5].

The particle track shown if Fig 6. Calculations were carried out in constant fields from quadrupole, kicker, septum, and earth magnetic field. Quadrupole and kicker coincides.

For prove calculation in BINP was build experimental facility (Fig. 7). Initial stage of experiment is providing beam propagation in direct channel without kicker excitation. We faced with serious problems in this stage. We could not get a passing beam with planning the number of magnetic elements. As result, there number was increased almost twice. We also observe the effects of

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beam instability during acceleration. It will be another investigation beyond this paper.

At present, the preparation of the experiment on the rejection of the beam by the kicker into the side channel is almost complete. The pulse generator has been tested. The circuit of connection of two pulse generators to one kicker is checked. The experiments are planned in May-June 2018.

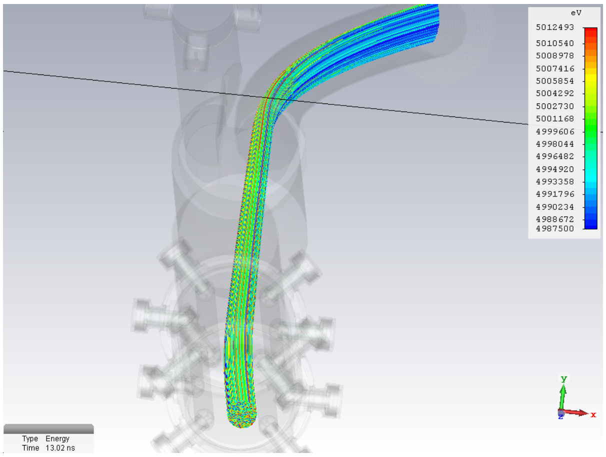

Figure 6: Beam tracking in CST.

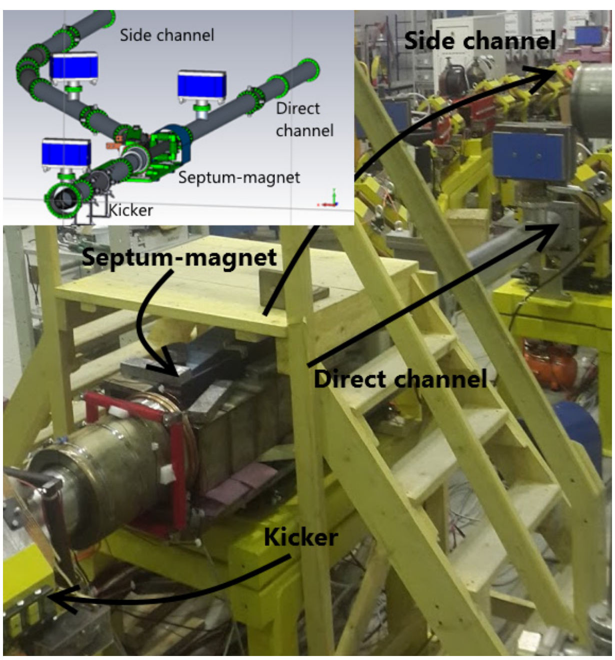

Figure 7: Experimental facility in BINP. April 2018.

SUMMARY

The design of non-conventional kicker was developed in BINP. It has carried out many simulations. However, we need to understand more closely the modelling of space charge in CST Studio. We also need to master the simulation of the wake fields and potentials in order to be able to predict the behaviour of the beam in the magnetic structure. Experiments preparation was already done. The experimental results will be processed and published in the near future.

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